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Team interactions in digitally mediated design meetings

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Dedication

For my lovely wife Cecilia and my beloved children Gyamfua, Darkoa and Ofori the most valuable people in my life whose sacrifice was so appreciated throughout this work

Declaration

I certify that this is my own work and the use of material from other resources are properly and fully acknowledged in the text

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Jacob Ofori-Darko

Abstract

The increasing demand for richer interactions in the design team and the reliance on digital media to facilitate their emergence tend to introduce a lot of dynamics into the exchanges that unfold in face-to-face design meetings. However, current knowledge on dynamics of exchanges in the design team appears to be insufficient to help enrich understanding of the nature of interactions in design meetings enabled by technologies in the digital space, although essential to inform planning of collaborative design tasks. The aim of this PhD is to better understand team interactions that unfold within the fluid digitally mediated design review meeting process; exploring the verbal and non-verbal actions that unfold and their effect on information representation and display medium during a face-to-face design meeting in an architectural practice. This aim was addressed through the following interconnected set of objectives:

1. Explore forms of information representations and display medium mobilised, and how specific features of the media are implicated to mediate the verbal and non-verbal actions of the design team during the meeting session;
2. Examine nature of verbal and non-verbal actions that unfold and their effect on use of information representations and display medium during the meeting session;
3. Explore the interplay that exists between different types of interactions in the design team.

This exploration was supported by the development of a conceptual framework that draws on concepts and techniques of mediated interaction approach (MIA) and use of technology in practice. To provide depth of insight and understanding, the research adopts a predominantly qualitative video-based approach with video recording and participant observation forming the primary techniques for gathering relevant data on verbal and non-verbal actions and activities of the team members during design meetings mediated by digital media in an architectural design office in UK. A total of five design meeting sessions stretching over ten hours of rich interactions in a single case architectural firm were captured as relevant data to inform the study. The study uses a coding scheme informed by concepts of the conceptual model; and principles of Interaction Analysis (IA) approach to analyse the ways design teams interact to communicate the design and perform collaborative task in meeting sessions. The analysis provides narratives of themes relating to team interactions occurring in the digital space: features of media, purpose of use of media, verbal and non-verbal actions in relation to information representation and display medium, and interplay between the types of interactions. The findings reveal in general, evidence of distinction between the medium and the representation of information in relation to how they mediate emergence and accomplishment of specific types of actions during the meeting session. The information representation, through key features such as, photo realism, walkthrough, and navigable informed types of actions undertaken by the team, whereas the display medium, with varying display size, interface and interactive features affected how participants experienced and interacted with the design. It was realised that verbal actions of the design team are mainly an iterative process of sharing understanding and addition of value to existing design decisions through descriptive, explanative and evaluative tasks enriched with gestural, viewing, navigation, annotation and on-screen manipulative actions across different forms of representations and display medium. The non-verbal actions of the team mainly involve information addition, searching and familiarisation of different aspects of design information, through fluid transition of viewing, navigation, annotation and gestural tasks interspersed with varying types of verbal actions across different display medium. The quest to richly engage with the evolving design and develop its content informed the design team to fluidly mobilise mobile devices, customise their experiences and enact different uses of the display medium

and information representation as well as user driven-tasks, however were accomplished in distinct ways, including group, sub-group and individual activities. Further, the instances of participants' verbal and non-verbal actions are all intricately connected and do not lend themselves to a clean separation in the team's interactions around the design information.

The research makes several implications, firstly to developers of digital technologies of the need to incorporate mechanisms into their new generation devices for smooth transfer and access to private and shared information with enhanced manipulative controls for better experience and interaction of design information; secondly architectural designers to allow flexibility in their design review meetings to accommodate individual and sub-group breakaways, and deploy digital technologies with enhanced features to support all the user-driven tasks during the meeting session; thirdly, that future researchers need to expand conceptualisation of interactions mediated by digital media to include individual and sub-group activities for in-depth details about nature of the interactions that unfold in the design review meeting session.

Overall the thesis conclude that digitally-enabled interactions in the design meeting is a fluid a process involving intricately interconnected verbal and non-verbal actions, hence successful transition between different types of actions, tasks and media assemblage are key to richer interaction during the design review session in the architectural design practice.

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Chapter 1 : Introduction

1.1 Background

The increasing complexity of building design projects and the demand for richer collaboration among participants in the design team have given impetus to digitally mediate the design review process. Mediating design meetings with digital media are expected to promote more opportunities for participants to interact among themselves and with objects in the design meeting. Digitally mediated design meetings involve a range of digital media with diverse capabilities, including interactive visualisation, virtual walkthroughs, annotation and mark-ups to facilitate the actions and activities of the design team (Fard et al., 2006; Liston et al., 2001; Mehrbod et al., 2019).

It is argued that mediated team interactions, which are described as interdependent processes of communications and actions of team members in relation to the digital media are the heart of the digitally-design review process, since through it participants are offered enormous opportunities to understand and communicate the design (Kalay, 1999; Kvan, 2000; Liston, 2009). By improving opportunities for greater exchanges among the team members and with technologies in the digital space, participants are better positioned to communicate about the design and effectively accomplish a design task (Kvan, 2000; Liston, 2009). The architectural design practice is confronted with the task of producing richer and better-informed design decisions meant to deliver a sound design solution fitting the client's requirements and user expectations (Gary and Hughes, 2007). However, attaining desired design outcomes necessitate that participants in the design team actively participate and engage in exchanges in the form of dialogue around the evolving design content (Liston, 2009). Therefore, mediating interactions in the design team with digital media in architectural design meeting process provides the opportunity for a considerable shift towards more sharing and critiquing of design information and ideas among the team members since relevant aspects of the design are revealed in such arrangements whereby digital media are incorporated to inform the team's deliberations.

Current research on interactions in digitally mediated design meetings has highlighted the key actions and tasks unfolding in the design team and their durations of emergence (Fard et al., 2006; Liston, 2009; Liu, 2016). Besides, other streams of investigations have touched on role and use of media in supporting interactions (Liston, 2001; Liston, 2009; Liu, 2016; Mehrbod et al., 2019; Tory, 2004; Tory et al., 2008). The overarching concern has been to understand the nature of interactions unfolding in the digitally mediated design meeting process in relation to the team members and with technologies in the digital space, and how digital media are used to mediate these behaviours. Bulk of these investigations have mainly used quantitative approaches to examine the fluid processes of communication instances and actions in the design team and have focused analysis at the higher-level of participants' interaction. The outcome of these studies has enhanced our understanding in a wide range of issues, including the role of media use in meeting interactions and relationship between use of media and participants' interactions (Liston, 2009); the value of virtual reality (VR) applications on post-occupancy design review meetings (Liu, 2016); nature and goals of team members interactions with building information modelling (BIM) tools and digital representations (Mehrbod et al., 2019) and characterisation of different ways participants interact with design artefacts (Tory et al., 2008). However, while these studies have advanced the understanding on nature of participants' interactions, the fluidity of the digitally-mediated design review process and the fine details of user-driven experiences and behaviours occurring in the design team essential to develop richer understanding are inadequately accounted for through such higher level of analysis and approach that examines such emergent and dynamic actions and practices.

However, in order to plan and achieve better interactions in the design team where range of behaviours in varying character needs to be accommodated to meaningfully shape the team's work flows, it is necessary to undertake a thorough investigation that focuses on interactions at the micro-level of analysis to enrich understanding into the dynamic and complex range of behaviours that unfold in the digital space, including verbal conversations of team members, their interactions with digital media, and how they mobilise and use digital media to support the team's workflows in the architectural design meeting process.

1.2 Problem Statement

The increasing demand for richer interactions in the design team and the reliance on digital media to facilitate their emergence tend to introduce a lot of dynamics into the exchanges that unfold in the design meeting (Jordan and Henderson, 1995; Kvan, 2000; Liston, 2009). These dynamics require adequate knowledge of the exchanges in the team to understand nature of interactions that ensue in the design meeting. The problem is that current knowledge on dynamics of exchanges in the team is insufficient to help enrich understanding of the nature of interactions in the design meeting. Most of the current knowledge on interactions supported by media in the design team are often approached from the macro level where types of actions are identified and their frequencies of occurrence quantified (Liston, 2009). This approach tend to provide little opportunity to qualitatively explore the fine details of interactions in the team, hence limiting understanding about the nature of the exchanges (Jordan and Henderson, 1995; McGrath, 1991). By qualitatively exploring the context of emergence of the actions and activities in the team, a lot of useful knowledge on when, where, how and why specific types of actions unfold are unpacked to yield depth of insight into nature of interactions in the design team.

Besides, most of the studies on mediating team interactions with digital media often conceptualise digital media as a solid monolithic entity employed to support the actions and activities of the team. Although the digital media has been found to encompass both the information representation and the medium with which the representation is visualised and interacted with (Cheng, 2003; Liston, 2009; Mehrbod et al., 2019; Whyte, 2002; Whyte and Nikolic, 2018). This conceptualisation tends to exclude valuable knowledge of the exchanges in the team since full details about the different components of the media are often not adequately addressed. Hence, these entities (representation media and the display medium) need to be decoupled in their involvement in enabling the verbal and non-verbal actions ensuing in the design team. Each aspect of the media is distinct to facilitate the actions and activities of the team as they have different features which could be used to stimuate different exchanges (Whyte, 2002; Whyte and Nikolic, 2018).

In the context of this PhD research, and consistent with prior investigations on use of information representations to aid the activities of the design team (Whyte, 2002; Whyte and Nikolic, 2018; Tory et al., 2008), media viewed as information representation denotes objects used to represent digital information of the design, such as, virtual reality (VR) models, building information models (BIM models), three-dimensional (3D) CAD renderings and two-dimensional (2D) drawings (i.e., plans, elevations, sections and details). In contrast, media characterised as display medium refers to computers, mobile devices (i.e., tablets, Smart phones), immersive visualisation technologies and other real life objects that are mobilised either to view, interact, manipulate or comment on design representations during the design meeting session. By accounting for each aspect of the digital media, knowledge of their salient features that are deeply involved in the exchanges in the team and specific ways by which they contribute to drive these exchanges are revealed. Since each way of looking at it has implications of how participants engage in it (Mitchell and McCullough, 1997; Whyte and Nikolic, 2018). Consequently, each of these dynamics matter in the way to approach interactions around the digital media since these have the tendency to provide new insight into the dynamics of the exchanges in the design team.

The limited knowledge of nature of exchanges in the team stands to affect adequate planning and organisation of rich interactions in the design meeting. The reason is that practitioners involved in organising design meetings may rely on the available knowledge to help mobilise and use relevant information representations and display medium to support the verbal and non-verbal exchanges in the team.

To address this problem, the current study argues that interactions supported by digital media in the design team are fluid and dynamic, hence need to be attached to the local context of its emergence to yield a useful understanding (Jordan and Henderson, 1995; McGrath, 1991). By situating the moment-to-moment acts of the team within the context of their emergence and accomplishment valuable knowledge of when, where, how and why specific actions and activities of the team unfold unveiled. Apart from lowering the approach of interaction to the micro-level, the current study seeks to consider information representation and the display medium as distinct entities involved facilitating the exchanges of the design team. The understanding of the nature of interactions within the context of its emergence and accomplishment, and distinctive roles of the representational media and the display medium can produce sufficient knowledge to help understand what the nature of interaction actually is in the design meeting.

This PhD research investigates the nature of interactions in a digitally mediated design meeting in terms of user-driven experiences and behaviours to understand the dynamics of the verbal and non-verbal exchanges that unfold to realise a design task. Digitally mediated design review meeting is a fluid and dynamic process situated within the local context of participants' actions. The participants in the design team perform tasks which often require customisation of user-driven experiences and undertaking of range of behaviours to respond to their needs. In this context, understanding and developing the evolving design thrives on accommodating the user-driven behaviours, including verbal actions, non-verbal actions and introduction of media over the course of the meeting. To develop detailed understanding of nature of interactions unfolding in the digitally-mediated design meeting process, there is the need to focus more on micro-level of analysis, where moment-to-moment and situated actions of participants, both verbal and non-verbal in relation to use of digital media are revealed. By approaching the investigation of interactions at that micro-level, essential details relevant to provide depth of insight into user-driven behaviours are highlighted. Besides, approaching the digitally mediated design meeting within the digital space as a fluid process allows the unpredictable and dynamic nature of participant's actions to be captured. Therefore, the research seeks to provide a detailed understanding of the nature of verbal conversations and non-verbal actions with reference to digital media as it serves to inform the planning and organisation of design meetings supported by digital media. Besides, the study explores how the media in the digitally mediated design meeting is utilised to facilitate emergence and accomplishment of participants' actions in an architectural design practice.

This research draws on group interaction process framework (GIPF), mediated interaction approach (MIA) and use of technology in-practice lens (UTIL) as a guide to explore the nature of user-driven verbal conversations and non-verbal actions that unfold to communicate and develop the design, and how digital media in the digitally-mediated design meeting session are used to mediate the actions. Specifically, GIPF and MIA will enable understanding of the nature of participants' actions to communicate the design and develop its evolving content through exploring the key verbal actions and non-verbal actions in relation to the media within the context of its emergence. From use of technology-in-practice perspective, the appropriation and enactment of use of digital media in their constituent parts- the information representation and the display medium; the salient features relied on and their ongoing and situated use to support the actions of the participants will become manifest. The findings to emanate from this analysis will facilitate the development of practical recommendations that could inform project architects and meeting facilitators in the design teams, as well as the digital technology section of the design firm to effectively plan for interaction-rich design meetings, mobilise relevant digital media and install mechanisms in the digital space to accommodate the diverse user-driven experiences and behaviours that unfold in the digitally-mediated design meeting process.

This PhD research offers several important contributions on team interactions in digitally mediated meetings. Firstly, it contributes to the current body of knowledge on team interactions in digitally mediated design review meetings within the architectural design practice by detailing the nature of interactions in the fluid digitally mediated design review process where scholarly work appears to be limited. Secondly, by examining the nature and details of verbal and non-verbal actions as well as emergent use of digital media in the team's workflows, this research offers practical recommendations for planning and organising design meetings supported by technologies in the digital space, thereby providing useful guidelines for enriching the meeting environment and the ensuing activities. In this light, design and project managers responsible for planning design meetings will be better positioned to make well informed decisions needed to encourage participants' involvement in the exchanges that unfold as well as comment on the evolving design. Finally, the findings of the study will highlight the key features of the digital media and suitability of the digital space in facilitating the user-driven actions and tasks emerging in the design meeting. Accordingly, designers of these technologies will be well informed based on the availability of empirical information to help incorporate needed improvements in their subsequent designs. In addition, the digital technology section of the design firm will be better positioned through this empirical information to make strategic decisions on investing in a piece of technology towards facilitating interactions in design meetings. These contributions will be presented as key recommendations towards the end of the thesis.

1.3 Research Aim and Objectives

The aim of this research is to explore the nature of team interactions that unfold within the fluid digitally mediated design review meeting process and how they are enabled by digital media in an architectural design practice. This involves a thorough investigation of verbal and non-verbal actions in relation to information representation and display medium.

Thus, the study seeks to achieve the aim through the following interconnected set of objectives:

1. To identify the forms of digital media mobilised and examine the salient features utilised to facilitate the actions and activities of team members during the design meeting session;
2. To explore how the design team uses digital media to mediate their actions and activities during the design meeting session;
3. To examine the nature of verbal actions that unfold in the design team and the role of the media towards its accomplishment during meeting session;
4. To examine the nature of participants' non-verbal interactions with the digital media (including display medium and information representation) and the effect of media towards its accomplishment;
5. To explore the interplay that exists between different types of interactions during the meeting session;
6. To provide a set of pragmatic recommendations for planning and organising effective digitally mediated design review meetings in the architectural design practice.

1.4 Research approach

The study employed qualitative video-based Interaction Analysis (IA) approach to operationalise team interactions mediated by digital media in the design review meeting, which has been viewed as the interdependent processes of verbal communications, non-verbal interactions with media and the use of media in the team's workflows. The micro-level and situated nature of this study informed the use of the video-based method and participant observation to capture the primary data for the study. Video-based qualitative research can be particularly relevant when investigating a social action at the micro-level of analysis where fine details of participants interactions unfold to realise a task (Corbin and Strauss, 1990). In this case, the concept of team interactions in the fluid digitally-mediated architectural design meeting process has not been comprehensively explored to provide a thorough understanding of nature of interactions unfolding in the design team, which are needed to inform effective planning of digitally-supported design meetings as well as designing appropriate digital spaces to enrich exchanges in the team. Hence, the video recording of interactions in design meetings as well as the participant observation were deemed appropriate in comparison with other alternatives to realise the aims and objectives of the study. The video data corpus was transcribed and analysed thematically with the help of Transana professional 3.21 video analysis software. The research process was divided into three key stages:

- **Phase 1:** an extensive review of literature drawing on relevant academic journal papers, conference papers, published and unpublished theses, books and online resources. The review begins with a highlight on the unique characteristics of digitally mediated design review meetings, specifically, the digital space and the ensuing activities. This is followed by discussions on team interactions focusing on communication instances to understand and develop design information, non-verbal actions to interact with information representation and display medium. The nature and characteristics of digital media as well as their mobilisation and use to support the communication instances and non-verbal interactions of the design team are critiqued using evidence from previous research and published studies.

- **Phase 2:** This is the empirical stage of the research in which a single case study approach was employed to explore the nature of interactions of team members and with digital media in digitally mediated design review meetings at a selected architectural design practice. This main stage was informed by the theoretical position of this research (i.e. team interaction process framework, mediated interaction approach and use of technology-in-practice lens) together with findings from the literature presented in Chapter 2. Design team meetings supported by digital media were video recorded and observed to obtain relevant data corpus on the nature of verbal conversations of the team members and non-verbal interactions with both the information representation and the display medium as well as how the participants mobilised and appropriated digital media to support their tasks at the finest detail.
- **Phase 3:** Covers analysis and discussion of the empirical material in more detail in the context of key issues coming from the earlier review of literature and utilising the study's theoretical framework provide appropriate recommendations to improve interactions in the fluid digitally mediated design review process.

1.5 Scope of the study

Team interactions mediated by digital media in design meetings encompass verbal conversations to communicate the design information, non-verbal actions to interact and develop the design information, and use of digital media which comprise the information representation and the display medium to support the task of the team (McGrath, 1984; Liston, 2009). The literature on digitally mediated design review meeting notices different dimensions to team interactions with respect to time and place, including synchronous-virtual mediated interactions; asynchronous virtual mediated meeting interactions as well as co-located digitally mediated interactions (Vijaykumar and Chakrabarti, 2007). Each of these dynamics may inform differently the nature of interactions that unfold in the digitally mediated meeting session. For instance, in face-to-face meetings, participants may have the opportunity to observe and respond to behaviours of other team members within the context of their emergence. However, for the purpose of this study, the scope of investigation is limited to face-to-face digitally mediated meetings due to the richness of social interactions expected to emerge in the physical presence of the participants. This stems from the fact that verbal and non-verbal actions of participants as observed in the ensuing exchanges may incite changes in the behaviours of other team members thereby introducing a lot of dynamics in the exchanges of the team.

Different design disciplines mediate their interactions with digital media during design meetings, hence may yield new insight into the discourse of team interactions supported by media. However, the current study focuses on architectural design practice due to its appropriateness in providing useful insight into the fluidity of the digitally mediated design review process at the finest detail.

Similarly, while several issues including background of the participants and nature of the task (McGrath, 1984) inform the nature of interactions that unfold in the digitally-mediated design session, the current study focuses on the verbal conversations and the non-verbal interactions around the digital media and does not provide analysis on the effect of participants characteristics, such as experiences and skills on the exchanges that unfold in the team. The reason is that the overarching concern of the study dwells on understanding in depth the nature of interactions that unfold around the digital media and does not seek to examine the cause and effect key variables affecting the exchanges in the team. Consequently, the emphasis of this empirical work is devoted to exploring nature of verbal and non-verbal, and how the features of both the information representations and display medium are implicated to support the tasks of the team within the context of the interaction.

However, while the study encompasses the verbal and non-verbal actions of the team members within the digitally supported architectural design review setting, the focus of investigation is mainly on purposes underlying emergence of the action (i.e. what the action is about), and how it was accomplished in relation to specific features of information representation and display medium. Hence, the study does not capture features of the verbal talks and the non-verbal behaviours in terms of their production, but on what the team members are doing in relation to the media while attempting to understand the design and make decisions toward realising the design deliverables.

1.6 Limitations of the study

Prior to discussing the theoretical, practical and methodological implications for team interactions mediated by technologies within the digital space in architectural design practice based on the findings of the research, key limitations are noticed. First, 5 meeting observations, spanning a duration of 11 hours from a single case architectural practice in face-to-face settings informed the research findings. Hence, the application of the results is limited to the selected case study in face-to-face design meetings. Although limited duration of design meetings recorded tended to affect generalisability of the research outcome in terms of coverage, these weaknesses have been accounted for through in-depth analysis of the data corpus bringing out richer insights into the nature of interactions that unfold in the digital space. Accordingly, the empirical findings from this study could be relied on to inform planning of design meetings, as well as designing of interactive digital spaces to support richer interactions in the design team.

Second, the research findings emanated from data corpus of the video recordings as well as participant observation of the actions and activities ensued in the design meeting session. Hence, interpretation of the meanings of the actions and behaviours of participants in the design meeting was subject to the researcher's personal interpretation without recourse to point of view of the participants. Accordingly, reliance on the researcher's own interpretation has the tendency to introduce bias into the meanings provided on the observed phenomenon, which in effect could limit the claims of the findings in informing new understanding of nature of interactions unfolding in the digital space. Nonetheless, while sole concentration of researcher's own interpretations of participant's behaviours in producing the findings appear to be a drawback to the outcomes of the study, the new knowledge produced by the study is relevant to inform theoretical and practical understanding of team interactions enabled by media in the digital space, since interpretivist tradition of knowledge from which the study aligns to supports construction of knowledge from multiple perspectives of interpretation.

Finally, although the process of team interactions supported by technologies is contingent on numerous social and material contextual issues, including background and experience of team members as well as nature and characteristics of the task and design project, the empirical investigation of this research only focused on media configuration and its situated use to understand nature of participants actions and activities in the digital space. Hence, clearer picture of circumstances and conditions necessary to inform emergence and accomplishment of participants' interactions might not be provided to fully understand range of behaviours combined to attain richer interactions within the design team. This limitation is to some extent mitigated on the premise that the findings of the empirical study served as basic information for further investigation on user-driven actions and activities in relation to use of technologies in the fluid digital space.

1.7 Structure of the thesis

The entire thesis has been structured into six chapters with this chapter dealing with the general introduction of the study. The description of the chapters is presented below:

Chapter 1 provides the research background, the research problem and outlines the study's core aim and objectives as well as the research scope, research output and the thesis structure.

Chapter 2 devotes to the review of relevant literature on team interactions supported by digital media in digitally mediated architectural design review meetings. The chapter begins with a review of existing literature related to digitally mediated design review process in architectural practice, articulating the digital space and associated activities. The review then critiques literature on team interactions, mainly concentrating on conceptualisation of team interactions and the underlying components. Accordingly, attention is directed to the communicative instances of interaction to understand and develop the design information, non-verbal actions employed to interact with information representation and display medium, and how digital media are mobilised and used to mediate the communications and actions of the design team. Further, it discusses the nature and characteristics of digital media (the information representation and display medium) assembled to mediate the team's tasks, the effect of digital media in facilitating the emergence and accomplishment of the actions and activities of the team members. The review also discusses the various ways with which the design team appropriate and use digital media in their workflows. The literature review identifies the research gaps and argues the need to account for the fine details and fluid nature of interactions that unfold in the design team to provide useful recommendations towards enriching team interactions in the digitally mediated design review meeting in the architectural design practice.

Also, the chapter presents the research theoretical framework that was utilised as a guide to analyse the empirical data collected on team interactions in digitally mediated architectural design meetings. It discusses the literature related to team interaction process framework, mediated interaction approach and use of technology-in-practice lens. The discussion covers the background, key assumptions and the main concepts employed to understand the under-researched topic of exploring the nature of verbal and non-verbal interactions and use of media in the fluid digitally mediated design review process in an architectural design practice.

Chapter 3 describes the research methodology positioning the research purposes, research design, and the research methods, namely, the video-based case study which was considered appropriate for investigating the research aim and objectives. Besides, the chapter provides an overview of the research approach and the justification of its selection in accordance with the aim and objectives as well as the theoretical framework of the study. Furthermore, the process of performing selected method to direct the data collection and analysis is clarified.

Chapter 4 presents the data analysis of the video data and discusses preliminary findings. It includes introduction of background of the design meetings under investigation and the analysis of corpus data obtained through the video recordings of design meetings supported by digital media in the selected case study. It also discusses the nature of information representations and display mediums mobilised and appropriated to facilitate the actions and tasks of the design team, the nature of communication instances and non-verbal interactions with media and the use and effect of specific features of the digital media in the emergence and accomplishment of the ensuing interactions.

Chapter 5 discusses the research findings and outcomes from the video data in more detail in relation to the literature review and relevant theories using examples from the findings.

Chapter 6 summarises the key research findings in relation to the aim and objectives of the study. Also, it discusses the research contributions by underscoring the fluid nature of the digitally-mediated design review meeting process and the distinctive role of ‘information representation’ and ‘display medium’ in facilitating participants’ interactions in the design team as different entities of the digital media, rather than lumping them together. Besides, the appropriation and customisation of the digital space and relevance of the mobilisation of personal technologies in supporting user-driven experiences and tasks are highlighted as significant contributions to literature and practice. Again, the chapter outlines the limitations and implications of this thesis and provides suggestions for further studies in relevant areas related to nature of team interactions in digitally mediated design meetings.

1.8 Summary

This chapter delineates the problem statement regarding team interactions in the fluid digitally mediated design review process in architectural design practice, specifically, the nature of verbal and non-verbal interactions in relation to digital media and how the media is used to support their emergence and accomplishment during the meeting session. The connection between the fluid digital space and the team's interactions was also highlighted in order to articulate the mobilisation and appropriation of the digital media to support user-driven experiences and tasks in the digitally mediated design meeting process. Lastly, the aim and objectives of the research were set out followed by a description of the research scope, outline of the main research approach and summary of the thesis structure. In the next chapter, the review of relevant literature and theoretical underpinning of the study is presented and critiqued.

Chapter 2 : Literature Review

2.1 Introduction

The increasing demand for richer interactions in the design team and the reliance on digital media to facilitate their emergence tends to introduce several dynamics into the nature of the exchanges unfolding in the team. To answer what is the nature of these dynamic exchanges in relation to the media is also messy, leaving a lot of knowledge about its nature missing. Hence, sufficient knowledge is still required for a detail understanding of the verbal and non-verbal exchanges as participants interact with the media. This requires the use of a robust approach, capable of unearthing minute details at the micro-level to explore the dynamic exchanges in the team.

This chapter provides a review of relevant literature on verbal and non-verbal interactions unfolding in design meetings in relation with the media and how the design team mobilise characteristics of the media to support their workflows within the context of digitally mediated architectural design meetings. The digitally incline context of interactions in the design team is first discussed to situate the relevance of this research and highlight the dynamics characterising details of interactions ensuing in the digitally supported design meeting. Besides, the general understanding of team interactions and how this affect the approach employed to explore the fine details of exchanges in the design team are discussed. Current empirical studies on nature of interactions emerging around media are perused to present an argument for a more micro-level qualitative and open-ended approach using the frameworks of team interaction process, mediated interaction approach and practice lens of use of technology within the larger context of computer-supported collaborative designing. The last section of the chapter presents and discusses the theoretical position mobilised to inform the methodological approach of the study.

2.2 Contextualizing team interaction in digitally mediated design meetings

The architectural design review meeting has been confronted with the challenge to provide more avenues for richer interactions among the team members since quality design decisions are expected to emanate from such engagements. This has led to numerous moves to mediate the processes and actions ensued in the design review meeting (Fard, 2006; Liston, 2009; Mitchell and McCullough, 1997). Mediated design meetings are a process used by a design team to understand and evaluate design decisions in environments where the processes and activities of the team are supported by digital media. By this, participants in the design team are envisaged to obtain more opportunity to create, share and use design information as they work to deliver a sound design solution meeting the clients' requirements and user satisfaction. More specifically, the need to deepen participation and engagement for better informed design solutions necessitate that participants in the design team incorporate digital media to aid their activities as they have the potential to facilitate the team's interactions (Mitchell and McCullough, 1997; Whyte, 2002). This means relying on the inherent capabilities offered by the digital media to enable the design team create, exchange and use digital information required to stimulate the exchanges in the design team (Liston et al., 2000). These activities permeate in the entire interaction processes of the design team such as the verbal communications, non-verbal interactions and performance of tasks required to enhance understanding and critical evaluation of design decisions (Liston, 2009).

Digitally mediated design meetings are the temporary interdependent processes of communication instances, interactions with media in the work setting and performance of task to produce sound design solutions (Liston, 2009; McGrath, 1984; Olson et al., 1992). Hence, interactions in the design team is heavily reliant on varying expected and unexpected behaviours of the team members. In this wise, participants are easily allowed to employ varying range of behaviours to support their actions and activities as they participate in the interaction process (Jordan and Henderson, 1995).

Equally, dynamic exchanges ensuing in the interaction process are affected by the context with which the actions and activities of the team members emerge, which encompasses both the social practice of the team as well as the technological environment of the work setting (Jordan and Henderson, 1995; McGrath, 1991; Orlikowski, 2000). Indeed, there have been several studies to explore the nature of interactions within the digitally enabled design meetings. To understand these dynamics in an attempt to appreciate the role of digital media as catalyst to facilitate the dynamic exchanges that ensue in the design team. Typical to these studies are the emergence and accomplishment of knowledgeable actions and activities of the design team and how the media is utilised to facilitate the realisation of the team's goals. More specifically, how various forms of digital media feature in the interaction processes such as communication instances, non-verbal interactions and tasks of the team members in their moment-to-moment acts (Liston, 2009; Liu, 2016). The digital media are means of supporting the creation, representation and display of digital information to facilitate the activities of the design team (Liston, 2009; Mitchell and McCullough, 1997; Whyte and Nikolic, 2018). This means the utilisation of various digital representational and presentational media to achieve the demand of this conceptualisation. However, if the digital media is to mediate the emergence and realisation of the team's actions and activities, it should align to the expected shift along the qualitative open-ended and content-dependent approach where the utilisation of the salient features of the media are situated in the workflow of the team. Orlikowski (2000) comprehensively conceptualise situated use of information technology of which digital media emanates as the process with which inherent features of media are incorporated into the realisation of the social action of the team through the emergent and ongoing activities of the team members. This definition captures among other things the capabilities of the media and their mobilisation as well as their purpose and situated use in the actions and activities of the team. The proceeding section highlights the complex context with which the essential processes of digitally supported team interactions occurs. Besides, trend in research approaches, empirical cases of their application are discussed to aid understanding of the need for a micro-level open-ended approach to unearth the essential details of interactions unfolding in the design team.

2.3 Team interactions in design

Team interaction is considered as a prerequisite in design collaboration, since it enables team members to integrate their expertise and create a desired design solution (Kvan, 2000). The concept of interaction has been conceptualized in varying dimensions. McGrath (1984) argues that team interaction is a continuous process involving communication and task performance among design teams. Through these engagements, members in a project team accomplish the goals of the project. Hence, in realising this, team members communicate and act together through verbal and non-verbal means. However, Liston (2009) argues that project teams also interact with the materials and tools within their work environment to accomplish project tasks. Hence conceptualisation of team's interaction needs include how technologies are employed to support team actions and activities (Liston, 2009). The current study aligns with this position on the premise that, interaction in AEC project teams, being it design, or construction stretches beyond communication and performance of task to encompass media use. Practitioners, in attempting to communicate and act together rely on the material environment of the task at some point to share and create information and develop understanding of the design. Hence, this study posits that discussions on team interaction be extended to cover the use and features of the media and the embedded data set to provide a comprehensive understanding of the phenomenon. However, whilst Liston's assertion is deemed appropriate, her conceptualisation of mediated team interaction does not account for how specific features and embedded information contribute to the use of the media as well as the interaction process in context of practice. The premise being that types of actions carried out with the support of technology coupled with how people use the media is contingent on media features and information Hence, the current study seeks to extend Liston's proposition by investigating the role of media features and associated dataset in team interaction within the context of practice to reveal in-depth knowledge how people interact in mediated environments.

In communicating to execute project goals, team members interact to exchange information and knowledge about the content of the design as well as construct mutual understanding of the design (Habermas, 1984; Valkenburg, 1998; Leicht et al., 2007). In the view of Haberman (1984), information sharing is key to achieving effective discussions among team members towards realisation of the team task. Several studies investigating group interaction process have considered exchanges among team members in terms of information and knowledge sharing, critical to the execution of the collaborative task (Fard, 2006; DeSanctis and Poole, 1994). This is due the fact that member's ability to contribute to the interaction process is partly linked to their awareness and understanding of the task content. This assertion about communication in team interaction is considered relevant in developing empirical understanding of design team interactions. The premise is that a lot of design activities rely on availability and adequacy of design data, and thus need to be supported for effective interaction. Again, design team members whether within the same discipline or different disciplines are meant to work together to deliver a shared design solution. Hence, individual understanding of the design content needs to be realigned to reflect the team's overall view (Kalay, 1999; McGrath, 1984; Habermas, 1984; Valkenburg, 1998; Leicht et al., 2007).

Consequently, developing a common understanding among team members about content of the task and expected solution becomes relevant for effective team interaction and as such key to contributing to the project goals. In addition to building mutual understanding about the details of the design, team members also carry out tasks such as decision making, problem solving and generating alternatives to accomplish project goals. Since teams interact for specific purpose, members' actions towards realisation of the team's goal become essential in the work of the members. These constructs relate specifically to task performance where behaviours and actions of members in the team results in a specific outcome or product. This study adopted the constructs such as decision making, creation/generation, negotiating due to their relevance to the discourse team interaction within design team meetings. This was done on the premise that members in design teams interacting to deliver a collaborative solution, often generate and choose alternatives considered relevant towards delivering the design product. Besides, teams negotiate to resolve misunderstandings during the accomplishment of the task at hand (Kalay, 1999; DeSanctis and Poole, 1994; Leicht et al., 2007). However, these activities, as posited, work together with the communication aspects for achieving the overall group outcome.

2.4 Mediated Team interactions in AEC

Empirical studies on mediated interaction in the architectural, engineering and construction (AEC) industry through various frameworks have operationalised team interaction by looking at communication instances at the micro-level. These studies have characterized such instances as descriptive, explanative, evaluative, predictive, and information sharing (Fard et al., 2006; Fard, 2006; Liston et al., 2000; Liston et al., 2003; Liston, 2009; Liu, 2016). The activities are mainly categorized broadly into lower and higher-level communication acts. Descriptive and explanative activities which mainly seek to develop understanding are considered as lower, whilst activities such as evaluating and predicting design decisions, which are connected to transforming design solutions seen as higher. Other instances such as making decisions, exploring alternatives and generating ideas have been used to operationalise task performance in the interaction process (Fard, 2006; Liston et al., 2003; Ofori-Darko et al., 2018). These frameworks situated on broader knowledge of social action and technology, have approached role of media in team interaction from varying perspectives. Whist some have considered both the characteristics and use of media, others have aligned mainly to their use (Fard, 2006; Liston, 2009; Leicht et al., 2007). For instance, Liston (2009), building on DeSanctis and Pooles' (1994) Adaptive Structuration Theory (AST) developed Mediated Interaction Approach (MIA) framework to investigate role of media use in team interactions. MIA considers the role of media in the interaction process. It provides a set of media use concepts such as communicative, information sharing and decision making, as well as purpose of media which are relevant in capturing instances of media use in team meetings. However, MIA does not address key aspects of media such as features and the data set, which are considered key in the AST conceptualization of media use (DeSanctis and Poole, 1994). Further, issues of context, for example, task characteristics and user experience and expertise, which have been argued to influence media use and team interaction have not been captured in the MIA analytical framework (Moum, 2010; DeSanctis and Poole, 1994). Hence, this study extends discourse of role of digitally enabled collaborative media by incorporating features of media, model content and the work context to empirically capture how specific features of the media as well as content of data represented are used to mediate team activities.

Whilst a lot of studies have sought to investigate role of media features in collaborative activities, variations of the medium and dataset have not been decoupled and interrogated (Fard, 2006; Moum, 2010; Leicht et al., 2007). Although, features of the medium provide useful insight to understanding set of actions promoted, the data set as argued possess varying forms of information relevant to stimulate different engagements with users in the interaction process (Moum, 2010; DeSanctis and Poole, 1994). Hence, stand to engage differently with different form and state of design data. The current study considers investigation of the medium and embedded data set as relevant for deepening understanding of role of media in team activities.

Despite these variations, studies on use of digital media in team interactions have contributed to the debate on media use in team activities. For instance, in a study conducted by Liston (2009) on role of media in shaping team meetings, within the environment of multiple media use, it was observed that team interaction changes across different medium. Liu (2016) in evaluating effect of virtual reality (VR) on design review for post-occupancy analysis where he compared VR with other media concluded that interactions vary across different range of media. However, issues on how the specific features of the media and associated data set are used to support actions and activities of team members within the context of architectural design practice have not received much discussion in these prior investigations. This development makes discourse on the interplay between team interaction and use of media inclusive. This study seeks to address these limitations by providing a detailed investigation on how design team members interact across different media with varying characteristics and dataset to accomplish collaborative design task.

2.4.1 Communicating design information

In digitally mediated design meetings, participants work together partly through verbal communication or talk to share information, develop understanding and modify design decisions with the purpose of obtaining sound design solutions (McGrath, 1991; Liston, 2009). Verbal talk is generally characterised as an utterance of a person in relation to understanding or developing content of the design. These utterances involve a series of behaviours, including the mode of communication, and the modalities used to create the talk (McGrath, 1984; Haberman and McCarthy, 1984; Gorse and Emmitt, 2007). Participants in design meetings employ different types of verbal actions through different processes to obtain understanding about the design and make decisions towards its realisation (Gorse and Emmitt, 2007; Liston, 2009). This PhD research operationalise verbal actions as any talk of team members directed to the information representation to understand and modify the existing design.

Depending on the perspective of approaching communicative action in interaction, verbal actions of the team can be viewed either in relation to exchanges in the meeting process or with the information representation employed to mediate activities of the team (McGrath, 1984). Communicative actions in relation to the information representation mainly concentrate on the specific types of verbal actions produced to understand specific design decisions, resolve challenges and update existing solutions of the design (Liston, 2000; Liston, 2007; Fard, 2006). In this case, the emphasis of the verbal utterance is placed on purpose of the talk in relation to the design representation since what participants verbally engage in to develop understanding of the design becomes the focus of the team (Liston, 2000).

Several studies (e.g. Liston, 2000; Liston, 2001; Liston, 2009; Alsafouri and Ayer, 2019, Liston, 2000; Liston, 2001; Fard, 2006; Liu, 2017) have been conducted to explore verbal actions of design team members around design information from both the perspectives of communication processes and communicative acts. For example, Liston (2009) with the aim of exploring processes leading to accomplishing the communication task in design meetings, conceptualised communicative acts into three different perspectives, including understanding-oriented; exchange-oriented and relational-oriented. These conceptualisations concentrated on the processes of communication employed by the meeting participants to verbally interact to develop the design. Liston developed themes such as grounding and describing to examine extent of seeking understanding of the design, while exchange-oriented used exchanging and structuring. In the case of relational component, the author described it as responding or initiating. By video recording interactions of project team members in design meetings, Liston analysed the video data thematically using constructs such as, grounding, describing, exchanging, structuring, responding and initiating. The thematic analysis was mainly based on the frequencies and duration of their emergence. Liston observed that participants in the meeting process mainly employ different processes, including exchanging, grounding and structuring to communicate among themselves via the use of different forms of media. The findings further noticed evidence of variation in the frequency of occurrences of communication types. The findings further noticed that extensive exchanging and grounding processes dominated the verbal interactions of the team members compared to structuring, initiating and responding processes.

The knowledge on extent of use of specific communication processes in design meetings has helped to further understand on how time is spent on the varying processes of communication needed to understand and structure the design. With this information, design and project managers, charged with the responsibility of organising effective and efficient team meetings can mobilise appropriate media to facilitate the undertaking of these communication processes. However, the analysis was limited only to the types of communication processes occurring in the exchanges of the team, without recourse to how these processes emerged with respect to their context. By focusing on distribution of the various communication processes, complexities surrounding these communication acts are missed out, thus reducing verbal behaviours of the team to mere numbers. The inability to provide rich details needed to enhance deeper insight into the dynamics of exchanges ensuing in the meeting process can affect successful organisation of design meetings. Unpacking the context of these communication processes and how they affect the occurrence and accomplishment of participants' conversations around the design is thus critical to enrich understanding of the nature of communication acts employed in the team (Orlikowski, 2000).

Other studies (e.g. Alsafouri and Ayer, 2019; Fard, 2006; Liston et al., 2000; Liu, 2016) have focused on exploring the types of verbal tasks implicated in the moment-to-moment act of the design team to obtain understanding and develop the evolving design. From this position, the interest of the authors hinges on the outcome or purpose of the verbal utterance contrary to the communication processes describing the ongoing conversations of the team. For instance, in a study to explore how participants communicate around project information to understand and take design decisions, Liston et al. (2000), through a field observation of construction project meetings, attempted to understand the existing approaches towards sharing of design information and the extent of facilitating decision making among project team members. The authors focused on the types of utterances with which participants in design team verbally converse around the design to discuss, resolve problems and take decisions toward improving the design solution. The concern of the authors centered on how to move the nature of verbal talk from obtaining understanding to that of evaluating design decisions. Liston et al. (2000) operationalised the communicative tasks of the project team members as verbal utterances of team members towards accomplishing a specific goal. Based on the purpose of the verbal talk, their study categorised verbal utterances of the team members as descriptive, explanative, evaluative and predictive tasks. The authors employed a wide range of evidences to practicalise the verbal utterances of the team. For instance, descriptive task was operationalised as verbal talk in the form of questions such as "what?, who?, when? and where?" often made in relation to project information to familiarise with the design content.

In the case of explanative task, question such as “why?” was used to ascertain utterances seeking to explain design decisions, while questions addressing “what does this means?, what-if ?, what happens when?” in the conversations of the participants were meant to identify tasks seeking to evaluate and predict decisions around the evolving design.

Their study observed that participants in design meetings iteratively move between different types of verbal communications, including description, explanation, evaluation and prediction to understand the design and take decisions to modify its content. However, variation often exist in terms of nature of the verbal task around the design information. The findings indicated that extensive descriptions and explanations are engaged to understand design decisions compared to evaluative and predictive communication tasks which are carried out to improve decisions around the design. From the perspective of understanding types of verbal utterances with reference to information representations utilised to mediate the understanding of the existing design, the identification of the key features of verbal actions employed by participants in the design meeting provides insight into the goal of verbal behaviour of project team members around design representations often employed to facilitate the task of the team. For instance, as pointed out by McGrath (1984), communicative task is a complex process which requires detailed understanding of the types of verbal actions engaged in to appreciate how the material context of the talk is utilised to support the activities of the team.

However, while the outcome of Liston et al. (2000) investigation has highlighted the various forms of verbal conversations around the design information, the scope of their analysis failed to capture the circumstances informing the emergence of these verbal acts since the context of participants' talk often attempt to shape the dynamics of conversations undertaken to understand and transform existing design decisions (Jordan and Henderson, 1995). Hence, unpacking the role the surrounding context of the various types of verbal tasks in relation to the representational media and the medium of display can provide richer insight into how these forms of talk can be attained to enrich the interactions of the team members around the evolving design.

Building on communication task classification method developed by Liston et al. (2000), Fard (2006) exploring how participants in digitally mediated design meetings interact with information representations characterised communication tasks around the design information as descriptive, explanative, evaluative and predictive tasks. The author concentrated on the extent with which these types of communicative tasks are implicated in the conversations ensuing around the design, duration of occurrence of these tasks and their effect in sharing and understanding content of the evolving design. By observing and video recording interactions of participants around information representations (3D models and 2D drawings) in a series of design review meetings mediated by interactive workspaces over a period of five months, Fard analysed the video data along three dimensions: communication types employed to interact with design information, identification of how time is spent on each of these communicative tasks and effectiveness of each of communication type in understanding and developing the design. The study noticed that participants in the design meetings supported by digital media engaged in extensive descriptive and explanative communication tasks towards understanding the existing design compared to evaluative and predictive tasks which focused on developing design decisions. The author concluded that emergence of effective communicative tasks requires variety of digital media with enhanced features to aid the dialogues and conversations of participants around the design.

The findings of the study have provided awareness on how participants moved across different verbal utterances to develop insight into the evolving design thereby contributing to transforming its content. The knowledge on how conversations around the design are distributed around the information representation can help designers of collaborative media to develop appropriate digital tools and media fit to aid the accomplishment of specific verbal tasks. Although these insights tend to enhance deliberations around the design since various types of dialogues are engaged to aid the work of the team members, the investigation did not provide details about how these varied verbal talks were instigated and accomplished. As argued by Orliskowski (2000), behaviours of participants in computer-mediated work context are complex in nature and take its structure in relation to both the material and social actors of the work environment. Consequently, answers to questions such as “when?, where?, how? and why?” can help enrich the understanding of the verbal interactions supported by digital media in collaborative design context.

2.4.2 Actions of participants around design information

McGrath (1984) considers the actions of the team around design information as important aspect of interaction among a group of people working together to accomplish a goal. The action component of the team can be viewed from different perspectives, including action as process of interaction and action as content of the task performed. By considering the task accomplished in the team, different components emerge to understand how the team realise the project goal. Different interpretations are often used to describe what participants are doing in terms of improving design decisions required to enrich the evolving design (Liston, 2009). Each of these characterisations employ different analytic themes to explore range of task with or without direct bearing to the design project. However, while different coding schemes used to explore the various tasks accomplished by the design team, they all converge on the main design elements (Olson et al., 1992). These descriptions, include identifying design issues, generating alternatives, choosing between different design proposals, and making decisions towards transforming the evolving design (Olson et al.,1992; Liston, 2009; McGrath, 1984). For example, McGrath (1984) in his seminal work on groups: interaction and performance, describe these components as activities to generate, choose, negotiate, and execute task towards developing the design solution.

Similarly, in a study to analyse collaborative activities in small design group meetings, Olson et al. (1992), focusing on the problem-solving activities of the design team, characterised task performance in the team as design issue, alternatives, clarification, goal, walkthrough, digression, project management, meeting management, summary and others. The focus was centred on both project-related tasks and non-project related task. The authors described project-related tasks as any activity which has direct bearing on developing the evolving design, while non-project related tasks concentrated on activities undertaken to manage the meeting process. Building on previous studies from the process perspective of accomplishing project goals, Liston (2009) also developed an analytic scheme to describe the processes undertaken to accomplish a project task. Liston interpreted the action process of the team as doing, coordinating, producing, and acting.

Alsafouri and Ayer (2019) in their study to explore how augmented reality (AR) is used to support design and constructability review activity used similar characterisations to analyse the various tasks undertaken by the team members to develop the design. Alsafouri and Ayer, used similar constructs, such as identification of issues, problem solving, generating design alternatives and decision making to analyse the various behaviours employed to realise the design solutions. The authors noticed that AR can support some of the actions of participants in digitally mediated design and constructability review meetings, including decision making, design alternatives, and problem-solving actions. However, variations exist in terms of how different mobile devices aided these range of actions around the design. The findings of their study help to extend understanding of how different mobile devices, such as wearables and handheld devices, with same technical AR environment, can introduce differences into the occurrences of actions among participants in relation to the design information. By acknowledging how different mobile devices can lead to different actions among the team members, selection of AR devices to mediate activities of the team can be done effectively to improve the design. However, the analysis did not account for which specific features of the AR device were used to mediate the actions of the team, and how these features were used during the design review session. As argued (Orlikowski, 2000; Jordan and Henderson, 1995; Maftei and Harty, 2015), the context of the action of participants in the design team often affect the behaviour of the team members in transforming the design. Hence, knowledge of how the messy environment of the task shape use of mobile devices to facilitate the actions of the team can provide better understanding of activities around the design.

The interest of these prior studies mainly concentrates on using analytic schemes which have the potential to analyse various behaviours employed around the design information to develop the design solution and manage the meeting process. These investigations have provided insight into key actions of the team members and extent of their use to improve the development of the design. In contrast, this PhD research uses constructs such as authoring, sketching and generating alternatives, evaluating proposed solutions and decision-making. These analytic constructs are mainly used to help identify the key non-verbal actions directly carried out to improve the existing design decisions. However, since actions of participants around the design information are argued to situate within the context of the interaction, the narratives of how these actions emerge in relation to use of specific features of the digital media (information representation and display medium) are provided to better enrich the dynamics of participants' non-verbal actions around the design. In this case, the emphasis of the analysis shifts from the meeting proceedings to the development of the design information. Hence, answers are needed to these questions: what type of action is produced to improve the design information? How do these actions emerge and accomplished? What specific features of the media are used to accomplish these tasks and how does realisation of these actions affect use of the digital media in the exchanges ensuing around the design?

This PhD thesis uses the term non-verbal action to mean any non-verbal behaviour of participants in the design team carried out to review and modify design decisions. Generally, participants in the design team interact around information representations through non-verbal actions to review and update design decisions. In reviewing design decisions towards modifying its content, the design team often identify errors in the design, generate different solutions and choose the best alternative relevant to improve the evolving design (Liston, 2009; Olson et al., 1992). Hence, the interest of the study focuses on issues such as identifying design issues, generating and evaluating alternative ideas and decision making.

2.4.3 Interaction with digital media

Participants in design review meetings interact with design information in different approaches and techniques to experience varying aspects of the design (Whyte, 2002; Tory et al., 2008). These techniques include viewing the design, navigating the design content as well as annotating, marking-up and gesturing (Whyte, 2002; Liston, 2009; Tory et al., 2008; Mehrbod et al., 2019). Generally, the techniques used to interact with various details of the design help participants to understand the design, identify errors and modify design decisions (Whyte, 2002; Tory et al., 2008). However, these interaction approaches tend to be affected by range of factors including the features of information representation and specific tools as well as the context of emergence and accomplishment (Orlikowski, 2000). Each of these approaches are discussed in the proceeding sections in relation to the information representation and display medium.

2.4.3.1 Viewing the design information

In design review meetings visualising design information is seen as important task through which participants in the design review meeting become accustomed to the content of the design. Viewing design information is a way by which participants involved in the design review process become familiar with the content of the design. Viewing design information in design review meetings enables people in the design team to understand the various aspects (Kalisperis et al., 2002; Mitchell and McCullough, 1995; Whyte and Nikolic, 2018). By familiarising with the details of the design, people obtain meaningful knowledge to inform their decisions about modifying the evolving design. Design information is represented in varying forms to enable participants (designers, clients, users) engaged with different aspects of the design. As argued by Scaife and Rogers (1996), information representations of objects are abstractions with which people experience the real object for meaningful decisions. Hence, representation of objects falls short of the reality in terms of level of detail of information revealed. The variations in the amount of design content embedded in the information representation suggests that different approaches are required to familiarise with various dimensions of the design (Chen and Stanney, 1999). By this, the nature of the representation and medium of displaying design content may incite different opportunities for people to see the pattern in the design since they possess different features. It has been observed that people adopt different approaches during design review meetings to visualise information represented in different forms. For instance, in a study to explore different ways with which participants in design meetings interact with design information, Tory et al. (2008) observed that people use varying range of approaches to visualise the design. Participants involved in the design review process often use varying range of ways to view different aspects of the design, including physical engagement with content of the design in specific display medium; cognitively familiarising with details of the design through varying range of techniques including verbal description and gestures. Hence, viewing design information is a complex process to understand the design content. For example, mobile devices with smaller screen sizes may introduce additional practical challenges, limited number of people to view the information at a time and undertaken of many manipulative actions to experience different aspects of the design (Whyte and Nikolic, 2018). These developments can distract participants from an engaging collaborative experience and lowers the flow of conversation during design reviews.

Many studies have been conducted to explore how participants in design meetings visualize design information to gain understanding of the evolving design, identify and address limitations in the design (Tory et al., 2008; Tory, 2004; Fard et al., 2006; Liston, 2009; Mehrbod et al., 2019; Ofori-Darko et al., 2018). Among these studies, the focus has ranged from understanding the behaviour of project teams while viewing design information displayed in mediums with different configuration (Tory et al., 2008; Liston, 2009), to effectiveness of specific information representations and projected mediums to aid viewing varying forms of information in design meetings (Mehrbod et al., 2019; Fard et al., 2006). Besides, others have concentrated on investigating nature of viewing design information within the context of digital practice (Ofori-Darko et al., 2018; Maftei and Harty, 2015), or draw attention to the dynamic nature of viewing task (Tory 2004; Fard, 2006).

Among these studies broadly linked to social and material context of the digital environment, the work of Maftei and Harty (2015), drawing on Schon's reflective practice, explored the behaviour of participants in visualising virtual reality (VR) model representation in a CAVE immersive virtual environment. Maftei and Harty, relying on video-based approach to observe how the project stakeholders, including the designers, the client and end-users, orient to the VR model and the CAVE technology to interact with different aspects of the design, indicated that participants exhibit elements of surprise in their encounter with the VR model and the CAVE technology, hence intermixing different actions to develop the design through the life-sized, feel of presence and physicality features of both the VR model and the CAVE technology.

By exposing dynamic aspects of the VR model via the display medium, stakeholders in the design review meeting obtain flexibility to experience different content of the design required to inform their decisions to transform the evolving design. The observation of excitement in behaviour demonstrated by the participants in the design team provides evidence to suggest that while configuration of media to support representation and visualisation of design information is crucial to enhance understanding of the team members, the context with which the information is viewed is equally important to affect the desired behaviour required to orient with the information. However, while the CAVE environment incited elements of surprise in the actions of the participants, Maftei and Harty's observation did not account for how the participants' orienting behaviour affected the implication of the unique features of the VR model and the CAVE technology in relation to their interactivity and photo-realistic nature. The attempt to exhibit specific types of behaviour within the context of the mediated environment can also incite variations in the uses of the features provided by both the representational media and medium of visualising design information. Acknowledging the behaviour of participants from the context of their emergence, and how the material features of the digital environment are utilised in the exchanges of the team members is key to obtaining insightful experiences that emerge as participants attempt to visualise the design for understanding and informed decisions.

The configuration of both the information representation and display medium as well as their mobilisation can shape how participants in the design team (Whyte, 2002; Whyte and Nikolic, 2018; Mitchell, 1994). Different types of representations and their attended projection medium have specific inherent features which indicate the amount of design content describing the evolving design. Hence, the level of detail of information representation reveals the functional characteristics of the design (Whyte 2002; Whyte and Nikolic, 2018). For instance, in a study conducted by Liu (2017) to explore the relevance of VR models in mediating the activities of design team members in a post-occupancy design review meeting. Liu attempting to develop better understanding of how the highly realistic representation of the design is utilised in the exchanges of the design, decided to compare the use of the VR model with other forms of digital representations such as 2D plans and elevations. The study concluded that both VR model and 2D representations are configured differently in terms of amount of information revealed to aid interactions around the design.

In a similar study to investigate the behaviour of people in their encounter with different configurations of representations mobilised in diverse approaches, Fard et al. (2006) observed that while variations in features of the information representation incite different actions around the design, how the representations are mobilised for viewing equally introduce changes in nature of exchanges unfold in the team. For example, Fard et al. observed in a design development meeting conducted under different ways of mobilising design information and projection medium that mobile computing devices, such as Tablet PCs, PDAs, introduced dynamics in the viewing practice of the design compared to fixed technologies such as the SMART Board. The differences in arrangement and introduction of the display medium to support visualisation of the design information necessitated that participants changes their approach to viewing the design information. Hence, the tendency for collaborative viewing of the design become disrupted in a situation where mobile devices are mobilised to display specific content of the design since they have smaller viewing size.

Consequently, obtaining a deeper insight about how participants view information under different arrangements requires that both the inherent features of media and how they are mobilised to mediate the actions of the team members are explored in greater detail.

2.4.3.2 Navigating the design information:

The interest in providing greater opportunities for participants in design review meetings supported by digital media (information representations and display medium) to encounter and experience varying aspects of design content have stimulated investigations to consider how navigation task is accomplished in the messy digital environment. Navigating or searching for specific content of design information is an act which enables people in the design team to access the required amount of information needed to understand and transform the evolving design (Jul and Furnas, 1997; Burigat and Chittaro, 2007; Whyte 2002; Whyte and Nikolic, 2018). Exploring the different ways by which a building design team interact with representational artefacts to coordinate the design activities in a design coordination meeting, Tory et al. (2008) in an ethnographic study spanning a period of seven months, observed that navigation plays a key role in the efforts of the participants to obtain relevant amount of information to inform meaningful discussions. This is because varying range of tools become available to aid the search task. The authors further indicated that complexities existed with the use of navigation tools in the realisation of task, hence configuration of navigation systems and organisation of representations be simplified to ease the task of searching for design information. In a similar ethnographic field study, Mehrbod et al. (2019) suggested that user friendly navigation tools are critical for successful execution of navigation task since participants in design meetings ae often require to combine and also switch between different views and representations to obtain alternative perspective of the design content. Furthermore, the ease of accessing different content of the design information in digital representations often appear to be affected not only by features of the navigation tool, but also by the nature of the representation as well as familiarity with the design content and manipulative skills of the users. For example, the ability to manipulate the navigation tools provided by the visualisation medium and the techniques for searching the needed information can help to easily accomplish navigation task during design meetings. Indeed, after providing user-friendly navigation tools to simplify searching for design information, the processes required to successfully locate the exact content and amount of information is also crucial to ensure successful navigation of design information since those processes drives the use of the navigation tools. As a result, it is important to ensure that workflows surrounding the use and search of varying aspects of the design are taken into consideration when attempting to explore how specific features of the information representation and navigation tools are utilised to help participants in the design team access different alternatives of the design (Whyte 2002; Jul and Furnas, 1997). The need to understand how specific features of the information representation and navigation systems are utilised in the team's effort to engage with relevant elements of the design, where for example, access to different characteristics of the proposed design can help provide an informed design decisions key to transforming the evolving design. However, attaining successful navigation task where difficulties of accessing the required information are reduced will require adequate awareness of the circumstances surrounding the emergence of the task since other issues of the material and social context of reviewing the design often affect how specific tasks are realised around the digital representation of the design (Cavka, 2010; Nurminen and Oulasvirta, 2008; Whyte and Nikolic, 2018).

2.4.3.3 Gesturing at design information:

The need to integrate content of information representation in design review meetings has increased empirical investigations into how gestures enable participants in the design team to engage and situate information representations into their deliberations around the design.

Gesturing or pointing to information representation is characterised as the movement of the hand demonstrating action or depicting spatial data in relation to content of the design (Detienne and Bekker et al., 1995; Visser, 2006; Murphy, 2005). The hand demonstration or movement towards the information describes the available content of the information representation in terms of their roles in revealing the various characteristics of the design (Visser and Maher, 2011).

However, as argued by Murphy (2005), gestural actions towards representations of design content reveals other characters of the design outside the representational media, since various abstractions of the design are limited in terms of meaningfully describing the overall functional characteristics of the represented object. Since gestural actions are required to perform different functions to fully integrate the information representation into the conversations around the evolving design need to be performed differently with different representations within the context of its emergence. To fully integrate the functional characteristics of the design which extends beyond the content of the information representation, different types of gestures, including pointing, spatial move, covering and parallel indication with different functions are employed to enrich the conversations around the design (Murphy, 2005; Detienne and Visser, 2006).

For instance, Tory et al. (2008) in a study to explore the various modes with which participants in the design review meeting interact with information representations and other digital tools employed to support the tasks of the team, observed that members in the design team used wide range of gestures, such as, pointing, covering, 5-finger pointing, interval, spatial move, parallel indication to meaningfully integrate the various representations mobilised (i.e., 3D models, 2D digital drawings) to mediate the understanding of the participants. The authors noticed a wide range of functions, including specific referencing, further description of the design, indicating location of elements, and functional behaviour of the design in practice. These expositions provide opportunity to appreciate the various dynamics surrounding gestural actions in terms of form exhibited as well as the underlining purpose and design representation. The rightful association of different types of gestures to their respective information representations can help to enrich conversations about the evolving design. However, the analysis failed to unpack the circumstances underpinning the emergence of these gestural actions even though the context of the action is argued to affect the nature of participants' behaviour (Orlikowski, 2000; Heath et al., 2000). The decision to employ a specific type of gesture to integrate aspect of the design information can be affected by the ensuing behaviours of the other participants collaborating to develop the design. Hence, acknowledging the social as well as the material contexts of the gestural action will help to provide a richer knowledge about the nature of gestures within the digital setting of the task.

In a similar study, Mehrbod et al. (2019) focusing on the information representation to mediate the tasks of design team members in BIM enabled design meetings, conducted a long term ethnographic study of project team to explore the interactions with which design team members utilise varying range of digital media to support their decisions on the evolving design. Apart from understanding the approaches employed to experience and interact with the BIM tools, the authors also sought to appreciate the challenges associated with the use of the information representations. By characterising interactions with BIM representation and projected medium using a taxonomy to identify the key actions and goal of their occurrence, Mehrbod et al. (2019) observed that the design team employ range of actions, including gestures, annotation and navigation to incorporate essential aspects of the design into their discussions. Their study further noticed that participants extensively employed gestures to gain attention of the team in relation to specific issues of the design requiring attention. However, the use of gestures in stimulating conversations about the design varied considerably across different digital representations, including BIM models, 3D digital representations and 2D digital drawings. The realisation of variation in use of gestures in different digital representations and display of information representation provides insight into how different forms representations are integrated into the conversations of the team in relation to the design. Since different representations reveal different aspect of the design content, gestural actions associated with each of the digital representations can help to augment the content of the representation in providing better understanding and engagement of the team members. While, the findings provide evidence of variation in the emergence of gestural actions across different information representations, the circumstances accounting for differences in gestural actions to secure attention and implicate content of the design into their discussions were not adequately addressed. Although, the level of detail of the information representation can incite different gestures to extend knowledge of the design, the nature of gestures and how they are realised to mediate the understanding and experiences of the team can equally be incited by the verbal and non-verbal behaviours of the team members as well as the features of the displayed medium (Whyte and Nikolic, 2018; Maftei and Harty, 2015). Hence, for deeper understanding of gestural actions in terms of their occurrence and accomplishment, the dynamics of the teams behaviours in relation to verbal conversations and non-verbal actions need to be considered since actions in collaborative space are better appreciated when situated within the social and material context of their emergence (Orlikowski, 2000).

While reliance on techno-centric approach to understand the nature of gestural actions in digitally enabled collaborative design settings is limited in terms of richness of information required to improve the use of gestures as a resource to understand and communicate the design, the context with which the gestural action emerges is considered key to develop a better understanding of the gestures as means to engage with the design content (Orlikowski, 2000; Maftei and Harty, 2015; Whyte and Nikolic, 2018). From the perspective of context dependent nature of accomplishing task in collaborative design meetings supported by digital media, Murphy (2005) through an anthropological fieldwork at an architecture firm in California, examined how the act of gesturing in relation to other resources, such as talk and design representations, are produced and used to facilitate collaborative imagining in communicating design information. Taking into consideration the material context of the environment (i.e., face-to-face design meeting), Murphy observed that act of gesturing is both a social and object-dependent act with which participants in the design meeting utilise to convey information about the design. By acknowledging that gesturing to communicate information about the design is aligned to other forms of behaviour, both verbal and non-verbal actions around the evolving design, the move to understand the use of gestures as resource to appreciate the design moves away from the individual act of gesturing to consider circumstances accounting for the emergence and accomplishment of the gesturer task. For example, by relating gestures to the surrounding conversations emanating from the content of the design, participants in the design process will be able to pay attention to nature of the verbal conversation and specific material components implicated in the interactions of the team. Hence, comprehensive understanding of the nature of gestural action as important means to integrate the content of the design into the exchanges of the team members require acknowledgement of the various dynamics of gestures in terms of form, purpose and the surroundings from which the gestural action evolve.

2.4.3.4 Annotating design information

Annotating design information in digitally mediated design review is a dynamic act through which participants communicate and manage knowledge about the design. During the process of transforming the evolving design, members in the design team engage with existing information to understand and modify design decisions through explanations, comments and suggestions (Lenne et al., 2009; Aubry et al., 2007). The provision of extra information in relation to the existing design enables the design team to update knowledge of the design and share this information to the relevant stakeholders involved the design project (Lenne et al., 2009; Marshall, 1997). Variations in knowledge of the evolving design, which come in the form of marks, text and symbols, are affected by many issues, including nature of the representation, the medium of display, and the context necessitating annotation of design information (Li and McMahon, 2009; Wang et al., 2011). The complexity underpinning the emergence and realisation of annotating design information suggests that both the mechanical aspect of annotation (i.e., addition of marks, text and symbols) tasks and the circumstances of occurrence are key to enrich understanding of the nature of annotation.

Various empirical investigations from diverse perspectives and approaches have been conducted to obtain insight into the nature of annotations employed to update and share design content. For example, from techno-centric perspective, where emphasis is placed on nature and capabilities of the digital representation and display medium, Lenne et al. (2009), investigated how digital media support annotation of 3D models in a collaborative virtual environment. Through an experimental study, where participants were made to annotate the 3D model and perform annotation-reading task in a controlled annotation task, the authors developed a 3-D annotation model, focusing on the form, spatialisation, and metadata of the annotation. Lenne et al. concluded that mark-up features of the virtual environment afforded the design team to add, index and filter different forms of annotation on the 3D model. Besides, participants demonstrated control of the annotation-reading task since users were able to find the needed information more easily and with a greater precision. While the experimental investigation did not provide ample opportunity to observe the behaviour of the participants in a messy natural work setting, which is considered key to appreciating the dynamics of nature of the annotation activity, the findings suggest that enhancing the annotation and mark-up features of a digital medium with which participants add comments on content of the evolving design can help enrich the decisions of the team. This is because knowledge of the current status of the design is continuously updated and shared among the stakeholders in the design project. However, circumstances engendering the undertaken of these annotation acts are required to fully understand the processes leading to the accomplishment of the annotation task (Orlikowski, 2000).

In similar study, Tory et al. (2008) conducted a study to examine how design team members interact with design information to develop the existing content in a naturally occurring design coordination meeting. The authors, through an ethnography study observed a real-life design meeting session of participants reviewing design for a period of seven months and developed a taxonomy to classify the different modes of engagement as well as circumstances informing their emergence. The authors observed that participants employed different approaches including, side-sketching and direct marking to add comments to the evolving design across different forms of representation (3D rendered images, 2D digital and paper drawings). The authors concluded that features of the representation and display media as well as purpose of their use introduce variations in the type and approach of commenting on the design. By accounting for circumstances informing use of specific approaches to update knowledge of the design, the link between annotating features of the digital media and workflow of the design team is revealed to help improve the activities required to update and share design knowledge to the participating team members (Whyte and Nikolic, 2018).

2.5 Digital Media

2.5.1 Conceptualisation of the digital media in design meetings

In collaborative designing, the use of media to support communication and interaction has been an integral part of the design process. The concept of media has received varying interpretations in literature due to its interdisciplinary nature. In terms of conceptualisation, Lanzara (2009) has defined media as 'any material carrier of objects and relations that function as signs conveying information and meaning'. Similarly, McLuhan (1964) posits that the media play a dual role within the context of communication in collaborative work parlance. To McLuhan, media not only conveys information, but also shape the content of information embedded. This assertion is also supported by Boujut and Blanco (2003) who posit that the characterisation of media encompasses the medium of representation, information and embodied knowledge. Hence, any discourse on role of media in design communication and collaborative working be approached from its duality of purpose- conduit of information representation and content of embedded information and knowledge. In terms of functional and technical capabilities, quantity and richness of information (i.e., variations in information content) communicated among teams become paramount in understanding a medium's relevance as argued by Daft and Lengel (1983).

Similarly, in understanding role of media in design communication, properties of the information or embodied knowledge have become central in such discourse. Characteristics of objects such as knowledge repository (i.e., embody knowledge of the design), boundary object (i.e., serves as interface between different communities of practice), and interpretative flexibility have featured greatly in understanding relevance of object or information in design team interaction and collaboration (Star and Griesemer, 1989; Ewenstein and Whyte, 2005; Luck 2007). For example, by considering information content in terms of interpretative flexibility, possibility for stimulating conversations around design information towards aiding understanding of the design among team members is enhanced. These classifications as pointed out in literature provide a foundation for developing comprehensive understanding of the role of media in design context from the perspectives of information content and capabilities of the media as conduit of information representation.

However, while information carrying capacity of media and embedded information content are considered crucial in understanding the role of media in design interaction, the ongoing and moment to moment use of media to aid the discussions and actions of members in the design team is also argued as significant (Liston, 2009; Orlikowski, 2000; Orlikowski, 2002; DeSanctis and Poole, 1994; Liston, 2009; Walter, 1996). The relationship between use of media and enactment of social action within situated work context thus cannot be decoupled from the discourse of media role in interaction. From the perspectives of Human-Computer Interaction (HCI) and cognitive Science, DeSanctis and Poole (1994) in their Adaptive

Structuration Theory (AST) have argued that media use and interaction in the context of work are bound together. Hence, understanding of how technology triggers action become shredded in complexity. They maintain that uncovering the complexity of media-interaction relationship is critical to understanding their interplay. Consequently, role of media in interaction should be approached from both its capabilities and context of use since when and how it is used have consequences on its effect in the production of communication and interaction (Liston, 2009). Apart from the complexities of technology-interaction relationship, Walter (1996) from the perspective of computer-mediated communication (CMC) have lend support to investigation on media use in interaction. In attempting to answer the questions, 'when are the effect of CMC a help or a hindrance', and 'how can the same group of technologies be described as a limitation and a liberation', Walther maintained that integration of media in constructing social action be given priority in terms of understanding its unique role in the production process of social action. These conceptualisations indicate that investigations undertaken to unravel relevance of media in social action such as interaction or communication in design collaboration context should approached comprehensively to understand the complexities surrounding its effect on the entire production process. These discussions have given credence to the complexity on the role of media use in construction of social action within a situated context. Drawing on these conceptualisations of media and complexity in use, this study argues that discourse of media role in construction of interaction /communication in collaborative design parlance be investigated comprehensively from the angles of their features, capabilities and information content as well as mode of use to understand their relevance in supporting collaborative designing.

Further, the type of media and its usage have been observed to vary in terms of form, physicality and interactivity as well as multiplicity of use (Orlikowski 2000; Liston 2009). The differentiation of media in terms in form, physicality and interactivity encompass simple objects such as sketches, drawings, to complex systems including multiple display systems, 3D interactive screens and virtual reality applications among others (Liston, 2009). However, recent developments in emerging applications of ICT utilisation in supporting collaboration, coupled with emerging digital practices, have increased research activities in digital media use in the collaborative design process (Cheng, 2003; Lu et al., 2015). This study on utilisation of media in interaction, thus concentrates on digital media use in design team interaction. The study uses the terms media and digital media interchangeably to denote how a piece of media or technology is used to support conveying of information or accomplishing a design task in the interaction process.

Digital media is described in literature as packages of computer applications, delivered through a set of hardware and software technologies, and configured as both system and medium for interacting, both with people and design information (Cheng, 2003; Churchill et al., 2001; Muramoto, et al. 2007). These technologies are used in different dimensions in the architectural, engineering and construction (AEC) industry to facilitate undertaking of collaborative activities. For example, in collaborative designing, digital media are deployed as either information authoring tool, or visualisation platform (Xue, et al., 2012; Lu et al., 2015). Digital media deployed to mediating interaction (i.e., facilitate mutual creation and sharing of information and knowledge) vary in dynamics. For instance, interaction can ensue either between individuals working in design teams, individuals with design information or both in design development process (Cheng, 2003). These features can allow design teams undertake possibilities of actions such as creation and modification of design information in real time, 3D experience of virtual spatial information as well as simulation of design processes, operations and activities (Savioja et al. 2003; Brooks, 1999; Cheng, 2003).

Accordingly, large portion of literature points to the potential of digital media facilitating information creation and sharing, as well as communication of design information among participants collaborating on design projects (Cheng 2003; Whyte, 2002; Liston 2009). Specifically, the role of digital media for supporting team interaction in collaborative design context, has been in some part tilted towards supporting information creation and visualisation, thus reducing mental loads of participants in developing understanding design of information (Cheng, 2003; Liston, 2009). These have often been accomplished through intuitive interaction with embedded information content, for example, 3D virtual model of the building, as it progresses throughout various phases of the design process or with the capabilities inherent in the media (Whyte, 2002, p.54; Liston, 2009). However, studies on media use in interaction have been approached from different perspectives and approaches and sometimes inconstancies emerged in their conclusions, thus limiting understanding on the phenomenon of role of media use in interaction production. The next section thus presents critical discussions relating to empirical studies on media in design team interaction.

Related studies of media use in design communication/interaction

The discourse of the role of media use in facilitating interaction among design teams in collaborative context has featured greatly in computer-supported collaborative working (CSCW), human-computer interaction (HCI) and design studies literature. Several studies have been conducted to explore how media use feature in the production of interaction/communication. These perspectives range from technology-centric, cognitive, socio-cognitive, social practice and workplace studies. The scope of these studies focusing on either media affordances, information content properties or usage dynamics have investigated media use in interactions in varying collaborative design activities.

For instance, judging from orientation of technological capabilities, Schouten et al. (2013) have investigated how functional affordances of 3D virtual environments (VEs) support shared understanding and group decision making in design teams. The authors through experimental design approach observed how design teams interacted in undertaking decisions on spatial planning issues. Their investigation revealed that interaction among teams to developing shared understanding in 3D VEs was better contrary to what pertained in text-based chat media. Schouten et al concluded that interactions in 3D VEs provided greater opportunities for enhanced team collaboration compared to conventional test-based collaboration technologies. Similarly, Schnabel and Kvan (2002), present an experimental study to investigate how a team of designers communicate design early ideas. They set-up a series of experiments to observe how the features of the media promoted creation and exchanging of information among individuals in design teams and concluded that communicating design ideas was more engaging in 3D virtual environment, however, constrained in some way by the environment.

These studies have provided some insight into potentialities of undertaking collaborative design task through technical and functional capabilities offered by the media. However, how the role played by inherent information content and conditions of use within the situated work context of the media were not captured in their investigations. Besides, reliance on experimental approach control occurrences of communication behaviours among design teams which naturally might be affected by the context of the collaborative activity. This thus places a limitation on their outcomes.

Contrary, other studies have looked at the use of media in design communication and collaboration in design teams, beyond technical features and capabilities afforded by specific medium in real-life design context. In these studies, attention was directed to the properties of the embedded information content of the media. For instance, Luck (2007) explored how the use of artefact in collaborative design episode might mediate understanding of design issues through conversations. The author relying on information richness and knowledge repository of the media coupled with its ability to aid interpretation opined, that information embedded in media enabled understanding of design issues to be shared among teams through interaction. Similar observation was also made by Whyte et al. (2007) and Abdelmohsen (2011) in their studies on media use and visual practice as well as BIM models in collaborative designing. Contrary to Luck's study, for example, Whyte et al.'s concentration of object or embodied design knowledge was placed on its visual representation characteristic. They argued that content of information provided, and variation in its representation had the potential to enable designers engage in collaborative activities to overcome their cognitive limitations during development of understanding of design issues. Their conclusion was that objects enriched with information had the tendency to facilitate development of understanding during design communication activities. However, Abdelmohsen (2011) on his part focused on the knowledge richness of the BIM model in facilitating convergence of understanding of design issues during development of design solutions.

Besides these investigations on the role of media in design communication and interaction, some studies have also explored the complexity of media discourse in situated work context. Liston (2009), drawing on DeSanctis and Poole's (1994) conceptualisation of media use and interaction relationship, compared occurrence of design teams' interaction across varying media spaces. Through development of a mediated interaction model (MIM) and observation of project meetings, the author concluded that individual's interaction behaviour changes across different media. Liston's investigation although highlighted how media is used in interaction, the scope of investigation mainly concentrated on behaviour of teams in interaction among themselves and with the media. However, description of the entire interaction process and how the media was utilised as a resource in the production of actions and activities in interaction, considered essential to understand the media-interaction tension as agued by Walther (1996), Heath (2000) and Lanzara, (2009) was not captured. The provision of information to understand unpack tension between media use and nature of interactions unfold in the design team is seen as key to appreciating the relevance of media use in interactions among design team members.

These studies report on aspects of the role of media in production of interaction among design teams in both experimental and workplace studies. Specifically, media's inherent features and information exchange capabilities as well as embedded information content have been considered as key to creation and sharing of design information in collaborative design practice. The complexities underpinning the use of media and interaction behaviour of teams have also been given consideration in prior studies. Conversely, how media use and interaction play out in entire interaction production process and the tensions ensuing thereof have not been comprehensively addressed in prior studies, even though considered relevant (Walther, 1996; Heath, 2000). This study thus seeks to contribute to this debate.

2.5.2 Information representation

Information representations are aspect of digital media through which content of the evolving design is revealed to mediate perceptions and experiences of participants in design review meetings (Whyte, 2002; Whyte and Nikolic, 2018). By approaching digital media as a representation, the focus turns to how participants in the design team can understand and use design representations to mediate their tasks around the design. Design representations are abstractions of the real building through which people perceive and experience the design content (Scaife and Rogers, 1996). By creating abstractions about the design, participants in the design review meeting obtain relevant knowledge to understand and inform design decisions. Design information are generally represented in different forms since variations exist in the amount of content available to mediate the experiences of the participants (Scaife and Rogers, 1996; Whyte, 2002). These graphical representations include, diagrams, maps, plans, animations, multimedia and virtual reality (Scaife and Rogers, 1996). As Gombrich (1982:173) argues, design representations do not provide a one-to-one relationship with the objects they represent, hence an awareness of this variation is key to affect how representations are selected to show the objects they signify. However, while representations are limited in the amount of knowledge, they provide useful information needed to meaningfully interrogate the design. Thus, the nature of the representation can affect how people experience content of the design (Radford et al., 1997; Whyte, 2002; Whyte and Nikolic, 2018).

Many approaches are used to characterise these representations of the design in terms of understanding their usefulness in mediating the actions and tasks of the design team. These characterisations include, the nature and inherent features of the representation, how they are mobilised and displayed as well as relative importance in supporting the task of the design team (Whyte, 2002; Whyte and Nikolic, 2018; Liston et al., 2001; Tory et al., 2008; Tory, 2004; Henderson, 1991; Pei et al., 2015). In terms of features, information representations have generally been categorised in relation to amount of design content abstracted by the media to enrich the understanding of the team members (Scaife and Rogers, 1996). These classifications include, iconic realistic models, such as virtual reality models (VR models), three-dimensional (3D) models, two-dimensional (2D) drawings and sketches (Whyte, 2002; Pei et al., 2015). Each of these types of representations provide different information about the design, hence used differently to mediate the experiences of the team members. For instance, Pei et al. (2015) conducted an empirical investigation to classify visual design representations used by designers in a literature review survey. By developing a taxonomy of classification with four different criteria, the authors classified representations as sketches, drawings, models, and prototypes in relation to precision and usability of the representation in revealing aspects of the design. Others, for example, Whyte (2002) grouped representations into two dimensional (2D), two and half dimension ($2_{1/2}$ D), and three-dimension (3D) and virtual reality (VR) models in terms of their uses and characteristics. Two-dimensional models which are mainly symbolic in nature provide knowledge about the spatial arrangements of the design as well as details of the individual elements required to inform decisions about the functional arrangements of the design. For example, 2D plans are utilised where appropriate to enable the design team to understand spatial considerations in the development of the design in a broader environment since the plan lays out all the essential information needed to decisions on spatial arrangements (Scaife and Rogers, 1996; Whyte, 2002; Pei et al., 2015). Contrary, 3D models, which provides a 3D and photo-realistic experience of the design helps participants to obtain sense of space and full-scale of the finished design. For instance, in a study to explore the value of VR models in a post-occupancy design reveal meeting, Liu (2017) observed that participants in the design review meeting had more opportunity to explore the VR model in terms of its 3D, interactive and full-scale capabilities. However, as observed by Whyte and Nikolic (2018), full appreciation of the 3D characteristics of the VR model may be reduced to 2 ½ dimension if the display medium does not support a complete emersion.

Each of these classifications provides different knowledge about the role of representations in the interactions of the design team. For example, in a study by Liu (2017) to explore the uses of VR models in relation to other forms of representations utilised to mediate the understanding and experience of the team in a design reviewed session, noticed that each form of representation play a unique role in revealing specific aspect of the design, hence the rationale of their use needs to concentrate on how the strength of one representation can be harnessed to complement the inherent limitations of the other. By focusing on unique role of each representation in providing specific knowledge about the design, different forms of representations will be combined to provide comprehensive information needed to transform the evolving design. However, Liu's analysis did not provide information about how the unique features of each of the information representations affected the experiences and interactions of the team members. The knowledge of how specific properties of a representation mediate the actions and tasks of the team members can differ in different circumstances (Whyte, 2002). For instance, a specific feature can help realisation of a task under a different context of interaction and disrupt the action in another situation (Tory, 2004; Tory et al., 2008). Consequently, situating the use of specific features within the accomplishment of the team's actions is necessary to enrich understanding of the use of each representation in the activities of the team.

Thus, the need to employ different representations with varying richness in revealing the design become necessary because each provides different knowledge about the design (Whyte and Nikolic; Liu, 2017). However, the process with which these combinations are carried out is critical for richer engagement among participants in the design team. Especially, either to use them simultaneously or in successive order during the interactions of the team. Any of these decisions has implications on the flow of engagement and participation of the team members in exchanges around the design (Whyte and Nikolic, 21018; Tory, 2004). The issue of transitioning between different modes of representation can be problematic if not handled well. Hence, irrespective of how they are used, there may be challenges to disrupt the flow and engagement of which they are introduced to support. Overcoming this will require support of effective medium, user friendly enough to handle how the varying range of representations are used to understand, interact and engage with the content of the design (Whyte and Nikolic, 2018). Thus, this current study argues that interaction exist between how the display medium and the representation are used to shape the range of behaviours exhibited. Hence, their interplay needs to be explored to fully understand their variations and synergies in relation to the task they support. By considering the on-going actions of the people engaged in collaborative tasks, relevant features of both the representation and the display medium likely to affect actions of the team members within the context of emergence are revealed. What is missing now, therefore, has been an effort to understand how the moment-to-moment actions of the design team members implicate specific use of features of the representation to mediate the task of the design team.

2.5.3 The display Medium

Experiencing relevant content of design in a digitally mediated design review meetings is a complex process which requires appreciation of the display medium alongside the representational media. Display medium is a means through which participants in a design team visualise and interact with varying features of the information representation to inform their decisions about the exiting design (Scaife and Rogers, 1996; Whyte, 2002; Whyte and Nikolic, 2018; Cheng, 2003). By this, members in the design team can modify their experiences with the information, since occasions may require for additional inputs and evaluation of outcomes to develop the design. Generally, display mediums are categorise as immersive systems, non-immersive systems and augmented reality systems (Whyte, 2002: 4-5). However, range of factors, including configuration of the medium (i.e., screen or display size, graphical interface, mode of input and the supporting software); nature of the tasks as well as user expertise and experience can affect how participants interact with features of the representation (Scaife and Rogers, 1996; Whyte and Nikolic, 2018). For instance, VR models, visualise in immersive displays, whereby the user is immersed into the virtual environment may experience and interact with the model in full appreciation of space and scale compared to a non-immersive system, such as computer screens where the model is only viewed a 2 1/2 dimensional representation.

Several empirical studies from different perspectives and approaches have attempted to explore the role of the display medium in facilitating the interaction and use of specific features of the representation (Fard et al., 2006; Fard, 2006; Kister et al., 2017; Ahsan et al., 2007; Baldwin et al., 1999; Johnson et al., 2002; Tory et al., 2008; Mehrbod et al., 2019). For example, in a study to explore how three-dimensional computer-aided design (3D CAD) tools are effectively incorporated into digitally interactive workspaces where many people work together to accomplish a design task, Fard et al. (2006), conducted an ethnographic study of a development meeting. The authors employed a video-based approach to record the activities of the team members at the design meeting in relation to how they use digital tools, such as SMART Boards, mobile devices (PDAs and cell phones) and 3D digital models to support their interactions around the design. By using observational logs and coding the various forms of actions and activities of the project team, Fard et al. qualitatively analysed the various ways with which members in the design team interacted with range of digital media mobilised to support the team's activities.

The study observed that participants engage with the 3D model via viewing, sharing information, annotating and marking up, demonstrating and brainstorming activities. However, mode of accomplishment differed across different digital tools due to variations in their features. The authors further noticed that specific features of digital media, including the touch-sensitive interface of the SMART board display and size of displays (mobile tools and computer desktop) incited different interactions with the design information (3D models). Besides, the study observed noticeable variations in mode of engaging design information due to differences in input and viewing features of the digital media, limitations existed in terms of collaborative access to personal information. While these findings on the use of interactive workspaces in design review practice have provided insight into the salient features of the digital media critical to facilitate key activities ensued around the design information in 3D mediated design meetings, details on how these specific features of the media are implicated in the interaction process to mediate the tasks of the team members is unaccounted for in the analysis. Knowledge about the context surrounding the use of specific aspect of a media in the ongoing activities of the team members is important to inform how the actions of the participants affected use of specific features of the media.

In a similar study, Mehrbod et al. (2019), with a difficulty of understanding how people in a BIM-enabled design coordination meeting often failed to use BIM tools to support their work, attempted to explore the interactions associated with BIM tools. Building on Tory et al's. (2008) work on characterisation of interactions with media, the authors conducted an extended (i.e. 2years) ethnographic study of a project team undertaking a design coordination of a new multi-purpose building project mediated by advanced BIM tools. Through the development of taxonomy representing the relationships between goals, artifacts, interactions and transitions in relation to the underlying processes of BIM-based design coordination meeting, Mehrbod et al. identified and characterised transitions with which participants switch between artefacts and views using the features of the BIM tool. The study realised that participants mainly employ approaches such as, preparation, annotation, navigation and recording to interact and engage with the BIM model to accomplish varying forms of goals including, securing attention, viewing, inspecting, documenting and querying. The authors concluded that with different forms of representations displayed through the same graphical interface, variations exist in how participants transition and interact with different features of the representation.

These findings have helped to understand the circumstances with which the interplay between the information representation and display medium can introduce variations in the nature and purpose of interactions around the design content. Hence, how representations are developed may affect how a given medium of display is utilised to support the actions of the team. However, the scope of the investigation or analysis did not cover the verbal talks which often characterise the exchanges that ensue in the design team, hence limit the outcome of the findings to non-verbal interactions. With myriad of interplays ensuing between verbal actions and non-verbal actions, which often incite different features of the representations to be involved in the on-going interaction process, how to situate the variations in the transitions between the different BIM tools become problematic when talk is involved in the exchanges. Thus, the scope of the analysis needs to be expanded to include the verbal interactions in these transitioning processes to better understand the complexities existing in the medium-representation interaction. The level of detail of the information representation as well as its interactive features can incite different forms of interactions with the design information, however, the extent of experiencing and engaging with content of the media may be affected by the features of the medium relied upon to interact with the design information (Whyte, 2000; Maftei and Harty, 2015; Whyte and Nikolic, 2018). Hence, insight on how the information representation and the display medium interplay within the context of accomplishing specific tasks of the team will help further understanding of the exchanges ensuing around the design information.

2.5.4 Usage approaches-mobilising digital media

The following sections discuss issues on usage approaches in relation to prior studies from digitally mediated interaction literature. Key emphasis is placed on circumstances of how digital media was incorporated in the interaction process to accomplish a task. The section discusses first the theoretical approaches to media use with which empirical cases of mediated interaction can be interrogated to appreciate the gaps that require attention. The mobilisation and use of digital media require that practitioners consider the context of use of the media and the inherent capabilities (Orlikowski, 2000). Within the domain of architectural designing, studies have indicated that several issues relating to circumstances of incorporating digital media do inform the process of use of the media in the interaction process (Chen, 2003). For instance, Liston (2009) proposes a mediated interaction approach model to explore media use at the team level. Liston (2009) concluded that qualitative approach to exploring the nature of actions and activities in the project team whereby the micro-level acts of the participants are aligned to the context of their interactions provided opportunity to capture all the essential processes of interactions at the various levels of the team's exchanges. Fard (2006) assessed how participants in design meetings supported by interactive digital spaces engaged with the media, specifically, quantifying duration of their use in accomplishing their goals; Fard et al. (2006) focusing on the use of technology to shape the interactions of the design team developed a set of requirements for effective utilisation of interactive spaces to facilitate design team activities; Tory et al. (2008) developed a taxonomy of interactions to classify the various ways the design team engage with physical and digital media for accomplishment of design goals in design meetings at the micro-level.

In a similar study, Mehrbod et al. (2019) drawing on Tory et al. (2008) approach to classifying low level interactions around media explored how participants in design meetings interact and transition between different BIM tools to realise a task. The implication of these studies is that there are a lot of social and material issues that tends to complicate the understanding of emergence and accomplishment of interaction in mediated spaces. Liston (2009) considers this approach in her attempt to explore the interactions around media use in technology-informed study. Techno-centric approaches often align to a fixed state and try to relate the emergence and accomplishment of interaction to the capabilities of the media that provides opportunity to gain insight into the actions and activities unfolding in the team. By contrast, Liston (2009) adopts a more qualitative, open-ended approach to describe the use of media in the interactions of team members, in which the richness of usage is aligned to the context of its occurrence. Liston (2009) considers incorporation of media to facilitate the exchanges in the team as a social process, enabling attention to be placed on the actions and activities of the team members. With this position, the understanding of the role of the media in supporting discussions and actions of the team moves away from the inherent capabilities of the media as utilised in the interaction process. Furthermore, every move to incorporate media in the activities of the team members has a link to the goals pursued by the participants in the project team. While this approach quite provides a comprehensive and structured way to account for the multifunctional and minute details of how media is utilised in the interactions among the team members, usage of media characterised as only a social process still ignores valuable details of exchanges around use of digital media with specific salient features (Orlikowski, 2000). Consequently, nature of use of media and the interactions generated partly link to the inherent features which are often relied on in facilitating the actions and activities of the team

(Whyte et al., 2018). Besides, since interaction is argued to be context dependent (Jordan and Henderson, 1995; McGrath, 2000; Orlikowski, 2000), consideration of the circumstances with which specific features of the media are used to aid the emergence and realisation of the team's ongoing activities provides more details about how media is used in the interaction process.

2. 6 Cases of team interaction mediated by digital media

Empirically, adopting an open-ended and micro-level approach to team interaction enabled by digital media with specific features tend to respond to the fluid and dynamic nature of social interaction or action by unveiling the minute details of the actions and activities from the context of their emergence rather than a generalised thing. For example, Liston (2009) argues that qualitative and context-driven approach to explore nature of interactions is better dealing in dealing with moment-to-moment acts of the team. Prior to examining the interaction process, the project teams had encountered wide range of multiple media in their meeting deliberations, including digital, paper and mixed media to aid their communication processes and evaluation of design information. Nonetheless, the key departure worthy of note in this exploration of meeting interaction is that there were opportunities to unearth valuable aspects of mediated interaction in the meeting context, such as communication processes, evaluating project-related information and resolving of problems both at the level of project goals and participant's interpersonal interactions. According to Liston (2009), these details of the interactions ensuing in the different project meetings observed were often lacking in prior approaches which have mainly concentrated on effect of the media. This broad detail of interactions unearthed in the project meetings as a result of the Mediated Interaction Approach (MIA) employed to capture the essential details of meeting interactions provided opportunity to delve deep into the various processes unfolding in the meeting process. While the MIA strategy helped to examine the varying range of processes, processes to communicate project information, handled project-related issues and evaluate project decisions with reference to project goals, interaction flow and socio-emotional needs of the team members, it is an indication of team interaction mediated by media in project meeting context where the socio-technical are required to yield depth of insight into the exchanges that unfold in the project team (Jordan and Henderson, 1995). This suggests that both the essential details surrounding use of the media and the mutual exchanges among the team members at their finest detail need to be captured to better inform the nature of interactions that unfold in the team. For example, the specific features of media utilised in the moment-to-moment and situated interactions of the team reveals deeper knowledge about the actions that emerge in the team meeting. As Orlikowski (2000) maintains, many actions and activities emanate among a team of people accomplishing a task in a technology supported environment since they rely on different behaviours and materials to accomplish their tasks.

Reflecting on how design teams interact to accomplish a design review task in a CAVE technology, especially the dynamic exchanges ensuing in mediated environment whereby participants in the design team orient towards both the technology and the information representation of the design at full scale, Maftei and Harty (2015), in their video-based study analyzing the interactions ensuing around an immersive 3D representation of a hospital design at full scale in a design review session, indicate that the design team switch between varying range of interactions in relation to the 3D immersive design information displayed in the CAVE technology as well as engaging with the CAVE technology itself to familiarise with the information in an exciting manner. In several instances, participants in the CAVE design review environment switched between interacting with the CAVE technology, engaged with the immersive representation of specific rooms in the hospital design and then embark on emerging issues to refine the design. This suggests that depending on which aspect of interaction process is pursued in the interactions of team members within a mediated environment, participants' encounter with inherent features of the media, both with the information representation and the medium of display, tends to introduce novel and array of complex interactions essential to refine the evolving design. Consequently, by orienting to the both the information representation (i.e. 3D virtual model) and the presentation media through their inherent features, the dynamics of participants' non-verbal interactions with which they engaged with the media in pursuit of their collaborative design task is unveiled.

Tory et al. (2008) investigated the use of representational artefacts to support design team activities by focusing on the dynamics with which the participants interacted with design artefacts during a meeting session. The study initially sought to classify non-verbal interactions ensuing in the design meeting and then identify challenges encountered with the use of the representational media. The aim of developing the taxonomy of interactions with the design artefact was to provide insight into the nature of non-verbal activities emerging in the design team in relation to the features of the media. During the meeting session, the participants in the design meeting were provided with the opportunity to interact with information representations which included 2D drawings in both paper and digital format as well as 3D physical and virtual models. The results of their investigation highlighted the principal interactions in relation to use of the design artefact to accomplish goals of the team and provided a recommendation to improve upon the non-verbal interactions around the representational media as well as the bottlenecks encountered. This outcome irrespective of the various non-verbal actions carried out to accomplish specific tasks during the interaction process suggests that interaction is a dynamic and complex process that must be aligned to both the material and the social context of the meeting setting.

The undertaken of different types of non-verbal interactions around the media and variations in their emergence also indicate the unpredictable nature of the exchanges that unfold in the team regardless of what form of behaviour is involved. This stems from the fact that by relying on different actions, the team will have to be flexible to allow easy switching from one form of interaction to another. For example, Tory et al. (2008) highlighted many occasions with which the design team had to engage in a back and forth actions to accomplish different goals while seeking to understand aspect of the design. On several occasions, the architect and the electrical consultant had to perform gestural, navigation, annotation and viewing actions back and forth to describe and illustrate different aspects of the design to the team members during the meeting session. In brief, while the switching between different non-verbal actions tends to provide opportunity for the team members to engage with different aspects of the design information, it may also introduce a lot of complexities which need to be accounted for so as to understand the minute details surrounding these occurrences. It also shows the context dependent nature of the interactions that unfold around the media as current goals of the team will necessitate when and how a particular form of action is undertaken (Heath et al., 2000).

2.7 Interactions in practice-complexities

The different aspects and approaches to understanding the nature of interactions unfolding in design teams attest to the complexity and messiness of the details of interactions supported by varying entities of digital media in design team meetings. This essentially encompasses the array of diverse verbal and non-verbal behaviours with which the team members carry out as they take turns to participate in the interaction process (Jordan and Henderson, 1995). Largely, this tends to enrich interactions through the dynamic exchanges among the team members and with various features of the information representation and the display medium via mobilisation and customisation of existing and available media in relation to the needs of the team. The scope and understanding of these dynamics continue to change as demand for richer details of the nature of interactions emerge in the wake of mediating interactions with technologies in the design meeting. Besides, depending on the focus of the investigation and the level of detail required, investigations into how these complexities play out to facilitate the emergence and accomplishment of actions and activities in the team may differ.

Moreover, the nature and type of information representations as well as display medium with which the team members may require to stimulate their exchanges tend to inform the type of action and activities to undertake as they seek to interact and engage with various levels of detail of the design, how to approach their engagement with the media taking into consideration the demand of the participants at the time. Consequent to these variations in the nature and features of the media as incorporated in the accomplishment of the team's tasks, the way in which participants assemble, mobilise, customise or configure digital media in their ongoing and situated activities becomes an important consideration in understanding the dynamics of the exchanges that ensue in the team. For instance, in a particular interaction encounter in which participants incorporate digital media to aid their representation and presentation of design information, the ensuing exchanges may demand that participants mobilise or custom specific features of the media critical to engender emergence and accomplishment of an action deemed relevant in their design tasks. Nevertheless, without flexibility in the workflows of the team, whereby participants can modify their user-driven experiences and introduce new media to support their turns in the interaction process, difficulties may occur in attempting to disrupt the team's workflows. This implies that maintaining fluidity in the exchanges among the team members and with their use technologies in the design meeting is required to ensure essential features of the representational and display media considered important in stimulating rich exchanges in the team within the context of the digital space. However, to facilitate this, there is a need to obtain a detailed insight into how participants adjust with flexible arrangements whereby individual members are given the opportunity to democratize their way of interacting and engaging with both the information representation and the display medium while maintaining the team's focus and contributing to the realisation of the task at hand. The attainment of rich interactions, a situation where participants are actively encouraged to contribute to ongoing discussions and comment on the evolving design thrives on participants ability to mobilise and customise their work context to suite the demand of the task at hand (Heath et al., 2000; Whyte et al., 2016).

Hence, seeking to obtain better insight into the nature of actions and tasks must be approached to situate the exchanges within the context of their emergence. In that way, its detailed nature is not evidence unless through the interplay between the knowledgeable actions, the salient features of the media mobilised and implicated in the ongoing activities of the team in relation to the circumstances. If the various interdependent behaviours of the mediated interactions can be greatly understood within the social and material, the aim to obtaining detailed knowledge about the nature of the dynamic characteristics could be obtained or attained.

There is significant academic and practical interest in the potential for digital media to improve interactions in the design team (Kalay, 1999; Liston, 2009). Nonetheless, the collaborations among the project team members often criticised as being saddled with inadequate interactions resulting in low quality design decisions (Kalay, 1999; Kvan, 2000). This is premise on the fact that, the utilisation of media, irrespective of capabilities of their inherent features is generally linked to the circumstances with which it is implicated in the ongoing tasks of the team (Jordan and Henderson, 1995).

Tory et al. (2008) as well as Mehrbod et al. (2019) provide a taxonomy to classify interactions supported by media in design meetings based on key actions and activities identified in literature and from empirical case studies. The authors divided the taxonomies to understand the interactions around media into different categories, including summary of goals, interactions and artefacts. The categories are arranged in what seemed to be relationships between the sub-themes. Nonetheless, a careful examination of the literature on each category suggests there are clear overlaps and interlinkages in the emergence and accomplishment of the various dynamics occurring in the design team in relation to the goals pursued by the team, the verbal and non-verbal interactions carried out and media mobilised to facilitate their realisation. These interconnections make it difficult to examine one part of the interaction process without considering the other aspects. This is more evident in the role of the material and social context in contributing to the understanding of the fine details of interaction as unfold in the design team.

Whiles there have been some attempts towards a robust approach to explore the nature of interactions supported by media in the design team at the finest detail. More specifically, the emergence and accomplishment within the complex and fluid arena of the work setting, there is ample evidence to speculate that the debate is highly contextual since local conditions within the team may require different actions to be undertaken to accomplish a task (Liston, 2009; Maftei, 2015). During the interaction process, team members find ways to articulate their views which may be unplanned. Consequently, multiple and divergent actions and activities emerging from the local context of the action. These are mostly unaccounted for as specified within academic and industry literature.

The context of the emergence of the interaction facilitated by information representation and display medium available in the work context brings bare the relevant details of the moment-to-moment acts of the team. More specifically, what is been done, when, where, how and why the actions and activities are carried out (Orlikowski, 2000).

Liston (2009) drawing on situated nature of interactions in project meetings develop a Mediated Interaction Approach (MIA) to analyse the fine details of interactions which considers the social and material context of participants' actions and activities. This is different from the more technology-centric approaches where emphasis is placed on the effects of the technologies in shaping the interactions of the team members. However, participants often have flexibility in relying on available or relevant resources considered key to facilitate their tasks, hence approaching it from a loosely or opened way stands to inject flexibility into the knowledgeable actions embarked upon. The Mediated Interaction Approach (MIA) framework offers some solution that enables communication instances, actions and media use during the interaction process to unravel the fine details of interactions (Liston, 2009). The MIA model is a framework based on communication instances, interactions with use of media in the accomplishment of the team's actions and activities and their interplay.

2.8 Theoretical position

2.8.1 Introduction

Issues related to mediated team interactions are often complex and multi-dimensional. They call on researchers and practitioners in collaborative work to unlock the opportunities for richer interactions among the participants in the design team and with technologies in the work setting. This demand for the attainment of effective exchanges in the design through the mobilisation and support of digital media forms the focus of the empirical investigation in this study within the context of architectural design review meetings. Consequently, there is a need to mobilise a coherent theoretical framework to enable comprehensive and detailed exploration of the wide range of behaviours that unfold while participants in the design team attempt to communicate about the design and accomplish a task. Team interaction process (TIP), mediated interaction approach (MIA) and use of technology-in-practice lens (UTL) frameworks have been selected in this regard (see Figure 2:3). This theoretical underpinning is aligned to the essential details emanating from the relevant empirical literature on the key actions and activities that characterise the nature of interactions among the team members and with technologies and how the technologies are utilised to mediate the acts of the team.

The rationale underpinning the adoption of TIP, MIA UTL is to provide a premise for an improved understanding of the nature of interactions that unfold in a fluid digitally-mediated design review process within an architectural design meetings-particular focus on the technologies mobilised to mediate interactions among participants in the design team, how they are utilised in practice and the conversations and actions about the evolving design. By utilizing these interrelated strands of frameworks to illuminate the often complex and dynamic behaviours that can enhance effective planning and organisations of richer interactions in design meetings supported by digital technologies. It has the capability to facilitate the identification and exploration of the ways in which interactions among team members and with technologies unfold in a fluid and messy environment where range of media are mobilised to facilitate their emergence and accomplishment in digitally enabled architectural design meetings.

This theoretical position also facilitates the exploration of how the design team used media in their ongoing communication instances to understand the design and accomplish a task, bringing into fore the circumstances of their use and the attended consequences of the exchanges ensuing in the design team. Specifically, the framework is employed to provide richer insight on the complex nature of interactions unfolding in the design team and the practices embarked upon to utilize the potential and capabilities of the media to mediate their actions and activities while communicating to comprehend and develop the existing design during design meetings.

The section starts with a sub-section on TIP which describes the key processes that characterise the interactions among team members through developing insight on the nature of conversations that emerge around the design and the types of tasks that are accomplished to develop the evolving design. Next, the MIA/UTL is presented as an appropriate lens to explore how the design team members use media in their ongoing activities to mediate verbal conversations and non-verbal interactions in relation to the media. It also discusses the types of media and inherent capabilities utilised to support the emergence and accomplishment of the team’s actions. Besides, how the media are mobilised and utilised in-situ to mediate the participants’ conversations and task in relation to context of their emergence are highlighted. All of these are essential components of using media in the ongoing and situated activities of the team. Hence, their consideration intends to develop a detailed understanding of the nature of behaviours unfolding in the fluid digitally mediated design review process. Additionally, it plays a significant role in the categorization of digital media usage around the evolving design in the selected design meetings that are analysed for this PhD. In brief, this section provides a robust framework for in-depth examination of participants’ communication instances, interactions with media and the emergent and situated use of media presented in Chapter 4 of this thesis.

2.8.2 Media interaction approach

Several studies have analysed these interplays at micro-level of team interaction and media using various analytic schemes. This study relied on the Mediated Interaction Analytic (MIA) scheme developed by Liston (2009) to empirically investigate the study of how the nature of dynamic exchanges unfolding in the design meeting. The interdependences of these concepts with team interaction are thus critical to providing justification for studying media use in design team interaction. These relationship as discussed summarises the interplay between technology and team interaction, and their contributions to the task outcome, and argues that the features of the media may contribute to trigger how teams use the media to communicate and perform task activities in the interaction process. The interdependences between media use and team interaction concepts are fuelled by the features of the media and other structures, which in consequence contribute to the task outcome. See Figure 1 for these independencies.

2.8.3 Practice lens of use of technology (use of technology-in-practice)

The practice lens of the use of technology referred to as use of technology-in-practice (UTP), is used within the context of this study as a framework to explore how the design team interacts with and use features of the media in their actions and activities during design meetings. The use of technology in practice lens was developed to supplement the prior structuration orientation on technology use by proposing a technology structure (set of rules and resources) as enacted through recurrent social practice of a group of users rather than being embedded in the technology (Orlikowski, 2000). This view direct research attention to what people do with technology in their everyday practice and how such use is shaped by the rule and resource implicated in their ongoing action. Use of technology-in-practice refers to the particular structure (rules and resources) of technology use that users enact when interacting with specific feature of the media in their social practice (Orlikowski, 2000). Consequently, these structures of technology [technology -in-practice] are not bound but enacted through the situated ongoing practices of particular users using particular technology in specific circumstances.

UTP argues that the recurrent use of features of a technological medium and its embedded content enacts structures (set of rules and resources) through the ongoing social practices or activities of participants engaged in a collective work. In turn, the emergent structures of the technology enacted tend to shape the use of the features of the technology utilised in the activities of the team. Further, UTP postulates that structures of the media are emergent through the repeated interactions of the inscribed properties of the technology in the ongoing and situated actions of the team. In reverse, the emergent structures inform how the features of the media are used (Orlikowski, 2000). In this case, the concept of 'emergence' as argued by becomes tied to the complex exchanges that unfold in the team and hence unpredictable (Orlikowski, 2000).

Consequently, the UTP lends itself well to capture the intricacies of the dynamic exchanges between the features of the media, the emergent technology structures and the ongoing social interaction unfolding in their activities. This is realised through the two distinct perspectives-technological artefact and use of the technology in practice. The technological artefact aspect of UTP concerns with how particular facilities provided by the media is utilised in the recurrent activities of the people. Contrary, perspective of the use of technology-in practice focuses on enactment of rules and resources (structures) which emerge through the ongoing exchanges of the team as they incorporate features of the media to support accomplishment of task. By this, both the actual use of specific features of the media and emergent structures required to inform the activities of the team are accounted for to appreciate the dynamics of exchanges unfolding around the media. UTS further assumes open-ended position regarding utilisation of the features of the media as well as the emergence of the technological structures. This allows the unpredictable nature of the use of media and the emergent structures to be captured in the ongoing social practices of the team since this position situate the incorporation of the media within the circumstances of its mobilisation. Recognising the fluidity in technology structure provides opportunity to understand circumstances -when, where, how and why people choose to change their interactions with specific characteristics as their activities progress (Giddens, 2013; Orlikowski, 2000).

Generally, UTS focuses on structurational processes of determining structures of the media through the recurrent social interactions of the team, however, the current study departs from this tradition to focus on the communication processes and the non-verbal actions participants in the interaction process (Figure 2.6). The rationale being that by the overarching concern of the study in understanding the dynamic exchanges unfolding in the social interactions of the team and how characteristics of the team are utilised to facilitate their task. Practice lens of the use of technology conceptualises the fluid and complex interactions ensuing in the team as mutual processes of utilisation of features of the media, the recurrent social practices and enactment of structures emerging in the situated and ongoing activities of the people. UTS mainly consists of three interconnected constructs, including interactions with facilities provided by the media, enactment of technology structures and the ongoing and situated actions and activities of users. The proceeding section highlights empirical applications of the framework and the constructs were mobilised.

2.8.4.1 Applications of technology-in-practice

The technology-in- practice lens has been applied to within different context of computer-supported collaborative work (CSCW) to examine the use technologies in the practices of a team of practitioners. The methodological approaches also differ, however, responsive to the variations whether using quantitative, qualitative or mixed. The following studies illustrate these dynamics.

Several studies attempt to examine the actual use of technologies with specific features in the ongoing activities of practitioners. For example, Liston (2009) in her study on mediated interactions mobilised the concept of enactment in the technology-in-practice model to explore patterns of interactions in team meetings at the micro-level. The three types of enactment- inertia, application and change were used to examine changes in the process in relation to pattern of use of media. Liston operationalised *inertia* as minimal use of media while *application* was referred to as using media to collaborate, solve problem leading to enhancement in the ongoing processes of the meeting. In the case of enactment as *change*, the study operationalise it as situations where media use results in improvisation and changes the existing processes carried out in the team. By observing various team meetings supported by varying range of media in design and construction projects, Liston identified similar patterns of enactment at a micro of analysis. The description of the patterns in process change as observed by Liston was analysed through a mediated interaction chart, referred to as MIA chart. The analysis revealed that interactions in the team meetings are dynamic and undergo periodic changes due to the extent of use of media. Hence, teams experience breakdown, maintain the status quo or attain synergy through innovative use of media in the meeting process. However, while the MIA chart in relation to enactment became useful in comparing the team's use of media and ensuing interactions in the meeting process, by ignoring features of the media in the enactment process, the analysis does not account for the relevant features of the media affecting media use in the meeting process and details of the dynamic exchanges required to enrich understanding about the nature of interactions unfolding in the meeting process supported by range of media. Furthermore, different circumstances during the meeting process tend to inform the extent of use of media, so to rely mainly on the enactment processes without recourse to context of their use leave out important details about the nature of dynamic exchanges unfolding in the meeting process.

2.9 Analytic model mobilised for the study

This section discusses the analytic model developed for the empirical investigation of the study. The model was mobilised based on prior applications of team interaction process (TIP) framework, mediated interaction approach (MIA) and use of technology-in-practice (UTP) lens in investigating the verbal and non-verbal interactions in relation to use of media. Additionally, the literature reviewed on team interactions in digitally supported design meetings also informed the selection of concepts for the empirical investigation. With reference to this research, the models were used as methodological framework to capture the minute details of verbal conversations and non-verbal actions of the design team and how specific features of the media were utilised. The models have been used to develop an initial coding scheme from which the empirical material was analysed to develop a narrative of the nature of team interactions in its minute form. The verbal and non-verbal interactions of the design around the media and circumstances of their emergence will aligned to constructs in the analytic model to describe the dynamics of the occurrences and accomplishments of the actions and activities in team.

Figure 2.1 presents the analytic model (mediated interaction approach and use of technology-in-practice) adapted to inform the empirical investigation of the study. Since the model is been applied to explore the dynamics of mutual exchanges in team around the media– the communication instances, the non-verbal actions in relation to the media, the situated and ongoing use of media, the purpose of use of media in practice and the features of the medium and embedded information content, arrows have been introduced. The reason is to echo the usefulness of the model to thoroughly explore the fine details of the dynamics of the verbal and non-verbal interactions around the use media in digitally supported design meetings and to move away from the quantitative and higher-level approaches interrogated in the literature review.

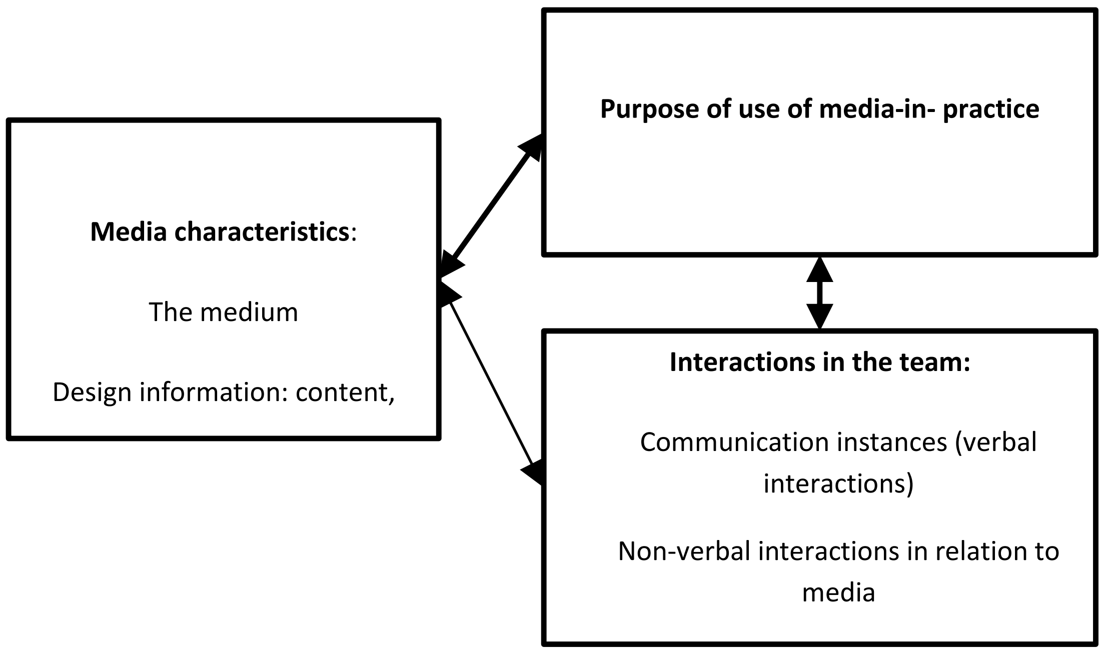


Figure 2.1: Analytic model of media use and team interaction (Adapted from Orlikowski (2000), and Liston (2009)

2.9.1 Team interaction constructs within the context of design meetings enabled by digital media

The proceeding subsections describes the constructs as used in this study. Each section explicates the construct and justifies its relevance in describing the details of interactions ensuing in the design team. The main concepts are also described to inform how the thematic analysis occurred.

2.9.2 Communication instances:

This view as argued encompasses among others, understanding the design and sharing information to develop the evolving design (Habermas et al., 1984; Liston, 2009; McGrath, 1984) information sharing is key to achieving effective discussions among team members towards realisation of the task. Several studies investigating into group interaction process have considered exchanges among team members in terms of information and knowledge sharing critical to the execution of the collaborative task. This is due the fact that members ability to contribute to the interaction process partly linked to their awareness of the task content (Liston, 2009; Olson et al., 1992). This assertion about communication in team interaction is considered relevant in developing empirical understanding of design team interactions. The premise is that a lot of design activities rely on availability and adequacy of design project data and knowledge, and thus need to be supported for effective interaction. Again, design team members whether within the same discipline or different disciplines are meant to work together to deliver shared solution meeting overall team satisfaction, individual understanding of the design content need to be realigned to reflect the team's overall view (Habermas et al., 1984; Kalay, 1999; Liston, 2009). Consequently, developing understanding about the design content becomes relevant to discuss and develop the evolving design.

2.9.3 Non-verbal actions:

McGrath (1984) proposed actions such as choosing, generating, executing and negotiating as key to accomplishing the goal of the task. Since team interactions are carried out for a specific purpose, actions of members towards realisation of the team's goal become essential in the work of the members. These constructs relate specifically to task performance where behaviours and actions of members in the team results in a specific outcome or product. This study adopted these action process constructs as bases to investigate empirically, team interactions in design meetings. This was done on the premise that, members in design teams in an attempt to deliver a collaborative design solution, often generate and choose alternatives considered essential towards delivering the design product. Besides, teams negotiate to resolve misunderstandings during the accomplishment of the task at hand (Kalay, 1999; Liston, 2009). However, these activities, as posited, work together with the communication aspects for achieving the overall group outcome. Thus, the processes of communication and task performance activities of teams happen during the interaction process. However, the magnitude of their occurrence dwells on the goals of the team.

In line with McGrath (1984) model of interaction process, communication and action process constructs become observable for analysis at the micro-level of team interaction. Hence, different analytical schemes have been developed to capture these observations during the interaction process. For instance, Bale (1950) work on interaction process analysis developed twelve observation categories to categorise activities and behaviours of teams along the three main activities (i.e., orientation, evaluation and decision-making) aligned with acts and behaviours of team members in the design process. These activities are either oriented towards the task or the socio-emotional needs of the team. Several studies on team interaction have adapted this observational category to analyse interactions among teams (Liston, 2009). This study adapted this coding scheme as modified in Liston (2009) study on mediated interactions in team meetings due to its appropriateness in capturing instances of activities and behaviours in teams during interaction at the micro-level.

2.10 Chapter summary

This chapter has reviewed key literature regarding team interaction mediated by digital media and approaches to their examination, positioning both within the digitally mediated design meeting to present the fluid and complex environment they emanate. The review has hinted different perspectives of the concept of interaction in the mediated environment as well as the key constructs defining the details of exchanges unfolding in the team during the interaction process that often tends to be ignored in relation to what the nature of interaction is.

It was argued that actions and activities in the design team aligns to the knowledgeable actions of the (i.e., verbal conversations and non-verbal interactions), how salient features of the media (i.e., information representation and display medium) in relation to the local context underpinning their emergence and accomplishment of team interaction in digital spaces and that conceptions informs the approaches employed to understand them (Section 2.3). In most cases, this tend to be relatively mechanistic and rigid in approach, ignoring the wider social and material context of their emergence and accomplishment rather focusing on discrete acts at the higher levels of interaction. On this premise, cases of interaction emergence concentrate less on the specifics of the local context which underpins the interaction process, assuming that interaction enabled by digital media are fixed and linear process to unfold. This PhD argues that the concept of team interaction supported by digital media in design meetings, the approaches to understand the details of nature of interactions and the deterministic analytic methods ensuing lead to impede the full understanding of the nature of interactions unfolding in the team. It again emphasis that, an open-ended and context dependent approach to explore the full details of the nature of actions and activities unfolding in the team, whereby the fluidity and complexity recognised aid unique course of action prescribed with reference to the social and material context of the team's workflows instead of a defined attributes detached from the local context of origin of the act, could provide a useful contribution to the team interaction emergence and accomplishment literature and help to inform the approach required to unearth the full details of interactions that ensue in the design team within the digital space as an approach.

On the premise to examine and begin to address the problems associated with the fixed conception of team interaction as well as its mechanistic approach to unravel the fine details of interactions, the literature turned toward the mediated interaction domain to assemble concepts and theories emanated from case studies examining the actions and activities of the team members digitally mediated with specific reference to architectural designing. This is because there is limited focus on the social aspects of interactions supported by digital media (Liston, 2009). In brief, although there is much research on design team on actions and activities around digital media in the design team (Liu, 2017; Fard et al., 2006; Mehrbod et al., 2019; Tory et al., 2008), research at the micro-level of interaction itself and how use of technologies affects the interactions.

When exploring the full details of exchanges that unfold in the interaction process grounded to the social and material context, the reality of emergence and accomplishment of interaction becomes manifest and the idea of team interaction mediated by media as fixed and mechanistic process becomes problematic. Furthermore, the move to simplify the emergence and accomplishment of participants actions and activities, tend to be inadequate, particularly in revealing the full details of the nature of interactions that unfold in the team, unpredictability of the existing interaction aspects, in relation to communication instances, interactions with media and situated use of the digital media are revealed alongside the context of their occurrence and realisation.

Hence, emergence and accomplishment of team interactions in digitally supported design meetings might perhaps be well understood by considering the fluidity and complexity found in such a context dependent setting.

The review has indicated a gap in mediated interactions literature relating to the conception of team interactions and the depth of nature of exchanges in the team. Principally, the approach to unearth the dynamic exchanges that unfold in the design team to respond to the circumstances informing the emergence and accomplishment of participant's actions and activities at the micro level of interaction.

This study seeks to respond to this limitation to add more emphasis on the fluidic concept of interaction as the approach to unearth the fine details of interactions in the design team. On this premise, this thesis proposes that design managers or meeting facilitators planning and organising design team interactions mediated by digital media may obtain better insight into the full details of what really the nature of interactions, and how they emerge and are enriched.

Chapter 3 : Research Methodology

3.1 Introduction

The aim of this study is to explore social interactions, such as verbal and non-verbal behaviours of team members mediated by technology in digitally enabled spaces within the architectural design practice. The chapter first revisits the underlying question of how teams interact in given ways when using specific interactive technologies during design meeting sessions. Second, it discusses the video-based Interaction Analysis (IA) analytic approach underpinning the collection and analysis of empirical data to address the concern of the study.

Third, the qualitative data collection methods assembled, and procedures carried out to obtain relevant data for this study are presented. Fourth, the chapter discusses the analytic techniques and procedure used to obtain the results from the empirical data. Finally, the research ethics and confidentiality governing conduction of the empirical investigation is provided. To address the question of how the design team interact in given ways when using specific interactive technologies, Interactive Analysis (IA) approach was used to guide the process of data collection and analysis of verbal and non-verbal instances of participants in design reviews (see Section 3.3 for detail discussion).

3.2 Overall research process

Although research on how digitally mediated spaces support design team interactions has increased in the wake of promoting efficient multi-disciplinary design teamwork, the discourse has mainly been concerned with the role of digital media and approached the digital space as a fixed system rather than fluid in nature. This suggests that digitally enabled spaces that contain multiple media open to improvisation and customization need to be conceptualized as heterogeneous (different media) and fluid (dynamic and changes unexpectedly) to better understand how team members interact in presence of technology. However, detailed understanding of what these interactions are in nature and how are they mediated effectively by technologies in the digital space during architectural design meetings is relatively limited, although essential to inform planning of collaborative tasks in the digital space. This study seeks to explore social interactions (verbal and non-verbal behaviours of team members) mediated by technology use in digitally mediated spaces within the architectural design practice. The study used the terms digital media or technology interchangeably and conceptualised it as any intervening agency by which participants in the design team relied on to support their actions and activities during the design meeting session. Hence, both the representation of spatial data as well as interactive medium that displays the information are considered essential components of digital media, since each entity mediates differently the way participants interact to communicate the design and undertake a collaborative activity.

The overarching concern of the study is: how do conversations unfold around the ways in which the team members interact with digital media (information representation and interactive medium) in heterogeneous and fluid digital space? Hence, the principal interconnected areas being investigated are as follows:

1. How the design team members interact with media and content of design information in digitally enabled spaces during design meetings in selected architectural practice?
2. What features of the digital space (media and information content) used by team members to communicate and perform specific task during the meeting session?
3. How do the design team members interact with each other in the design meeting when communicating the design and performing a task?
4. How do the types of interactions affect each other (interplay) while the team members communicate and perform task in the digital space?

These objectives were pursued through two main research phases: research focus phase, and the main video-based case study phase. The initial phase contributed in shaping content of the main stage. The research focus stage, which constitutes the initial phase of the study, was carried out to review relevant literature on mediated team interactions, specifically, face-to-face and collocated settings in design and related disciplines, and develop an analytical model of key constructs underpinning mediated team interactions to inform the analysis of the empirical data. The main video-based case study phase was carried to obtain relevant video data from naturally occurring design team meetings in a selected architectural design practice. The next section provides overview of the video-based Interaction Analysis (IA) research approach employed in conducting the empirical work.

3.3 Video-based Interaction Analysis (IA) research approach

This study adopted qualitative video-based Interaction Analysis (IA) approach to operationalise team interactions mediated by digital spaces, which has been conceptualised as interdependent processes of communication, action and use of media in the team's workflow at the micro-level. Interaction Analysis (IA) is an interdisciplinary qualitative approach to studying the micro-level interactions of human beings with each other and with objects and artefacts in their environment (Jordan and Henderson, 1995, p.39).

The fundamental assumption of IA is that practice and action of people engaged in collaborative work are social in origin, organisation, and use, and take their meaning within the context of a particular social and material environment (Jordan and Henderson, 1995, p.39). Hence, what people do, and behaviours exhibited when engaged in a collaborative task are situated in the interactions between members of a community engaged with the material world, and as such, tools or artefacts within the work environment have the potential to shape participant's behaviour in interactions. For example, as observed by (Jordan and Henderson, 1995), the behaviour of team members engaged in viewing information on large displays tend to change when media, which does not support multi-user viewing, is introduced in the process. Furthermore, IA assumes that analytic knowledge of the world of practice should be at least understood from evidence emanating from the naturally occurring actions and activities as they unfold within the work context. This perspective suggests a commitment of IA to grounding theories of practice and action. While empirical work in IA approach can be informed by prior theories and concepts underpinning the phenomenon under investigation, this should be done loosely to align to empirical evidences driven by the emerging data.

The goal of IA, thus is to investigate actions and activities of people, including talk, non-verbal interaction, and the use of technologies within the situated work context. IA accounts for the routine practices and how team members resolve any emerging challenges while interacting to accomplish a task. Consequently, IA comprehensively addresses both verbal and non-verbal aspects of human interaction to capture the team members conversations, their visible conducts as well as interaction with technologies in accordance with set principles, processes and procedures. Hence, IA orientation yields deeper insight into the complex array of behaviours that unfold when participants in a team engage in interactional exchanges to accomplish a goal in an open-ended and unpredictable social and technological environment (Bucciarelli,1988; Jordan and Henderson, 1995, p.39). It provides opportunity to investigate human activities accomplished in a complex, messy, multi-actor and technology-mediated work settings.

Interaction Analysis, which sits within the broader tradition of ethnographic participant observation and conversation analysis (CA), primarily uses video recording as the principal technique for obtaining empirical data (Jordan and Henderson, 1995). The video recording has the capability to capture a range of behaviours including talk, body conduct, practical actions and interaction with technologies within the work context. Linking IA's position and method of inquiry to the interactions between team members who generate, exchange and use information in a digitally mediated design review task, some parallels could be drawn. The premise is that collaborative design task primarily happens through occurrences and interlinkages of the team's verbal conversations and interactions with technologies within the work context. For example, in his seminal work on mediating interactions, Kvan (2000) maintains that team members engaged in a collaborative activity supported by technologies, are required to interact with one another as well as with features of the technology in order to accomplish the design task. This indicates realisation of collaborative design task among the team members is driven by both verbal utterances of the members as well as their nonverbal actions in relation to the media. Hence, a verbal behaviour may trigger occurrence of a nonverbal behaviour and vice versa as the team members engage in the exchanges around the evolving design. Similarly, Bucciarelli (1988) has observed that participants in a design team engage in a variety of activities and actions to accomplish a collaborative task and that these behaviours tend to influence each other. While conversing to progress the design, the team members interact with design information and relevant facilities to enhance understanding and take informed decisions about the design.

Although other methodological orientations such as Conversation Analysis (CA) and Ethnomethodology (EM) share similar approach to the study of social interaction around technologies, IA's treatment of context and turn at technology in the activities of people is considered very convincing. Consequently, Interaction Analysis approach provides an opportunity to investigate in depth the complex interaction exchanges, including both the talk and the technology in the process of communicating the design and accomplishing tasks during the design meeting session. The decision to adopt IA approach is influenced by its consistency with prior investigations (Liston, 2009). For example, Liston (2009) used IA to develop a mediated interaction framework to study the role of media use in team interaction. Although prior studies sometimes combine IA with other methods to respond to their analytic interest, the application of IA to study both talk and use of technologies in naturally-occurring settings has been robust to capture empirical data at the level of detail required to yield the relevant findings to address the concerns of the study (Jordan and Henderson, 1995).

In this regard, since the goal of the study is to explore how conversations unfold around ways in which team members interact with media and content of design information in heterogeneous and fluid digital space, IA approach is considered appropriate to inform empirical investigation of team interaction supported by digital spaces in architectural design meeting settings. The subsequent sections discuss how IA method was empirically carried out to gather and analyse relevant data to respond to the overarching concern of the study.

3.4 Case study design

This section is devoted to discussions of the study case underpinning the empirical work. The section comprised setting of the study, study population, sampling and access to data.

3.4.1 Study setting

The research focuses on design team, specifically, their interactions in design meetings mediated by digital spaces. The setting of this study was an architectural design practice in the UK construction industry. The rationale for this choice was twofold. First, there is evidence that many interactions needed to inform design decisions occur in the early phases of the design project, where the architectural design practice is charged with the responsibility to see to its delivery (Kalay, 1999). Second, many activities on production, exchange and use of information in relation to the building design project take place in the architectural design phase of the project (Kalay, 1999; Kvan, 2000). Hence, the potential to observe wide range of interactions among the team members in design meetings, coupled with the richness in information related activities makes architectural design practice appropriate setting to empirically investigate how the design team members interact, both with themselves and with the technologies in the digital space while they communicate and develop the design.

In view of confidentiality and nature of agreement entered with the participating architectural design practice, the name of the firm is withheld, and hence referred to as the design practice/firm. The design firm is a reputable architectural practice in the UK, which places technology and innovation at the heart of its practices. Specifically, it has implemented building information modelling (BIM) and its related visualisation technologies as methodologies to drive its processes and workflows[1]. Consequently, the firm has setup three digital meeting spaces with varying technologies to help collaboratively produce, share and use digital information. These digital spaces vary in configurations in terms of technologies and other facilities assembled. The first meeting space, referred to in this study as digital space 1, is configured with a multi projector array which creates a virtual environment across three synchronised screen enabled wall surfaces to display varying sets of data. The multi-screen wall surfaces are 1500mm high and projected 750mm above the floor level and 600mm below the ceiling. In addition, the display surfaces can serve as a digital whiteboard to enable

[1] http://www.ribacharteredpracticesdirectories.co.uk/riba/thelist/2018

participants in the design team mark-up on screen drawings. Besides, the digital space has an activity area, arranged with a working surface (table) and chairs to facilitate team activities. The seating arrangements are flexible enough to allow space reconfiguration in the team's activities during the meeting session. Fluidity in the space allows incorporation of other media, including mobile/personal devices such as tablets and smartphones to supplement the main multi-screen display. The schematic setup of the space is presented in Figure 3.1.

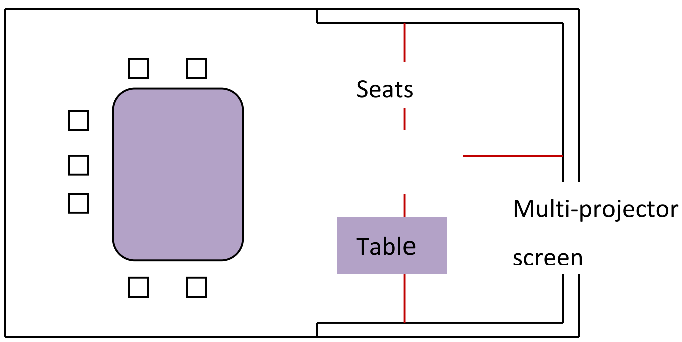


Figure 3.1: Set-up of digital space 1

The second collaborative meeting space (digital space 2) is configured with a large wall display screen driven by powerful PC connected to a local or cloud server. The large wall display support visualization of varying forms of digital information including virtual reality (VR) models, digital 3D CAD renderings among others in large sizes during design meetings. Apart from differences in mode of visualisation, the setup in terms of seating arrangement and introduction of personal devices such as tablets and smartphones remain the same as digital space 1 (see Figure 3.2).

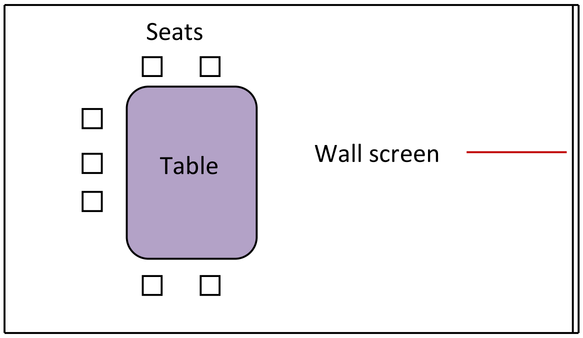


Figure 3.2: Set-up of digital space 2

The third meeting space (digital space 3), has a SmartScreen display, table (working surface) and seats. The SmartScreen has a touch-screen interactive interface which enables team members to physically manipulate digital information. The arrangement of the activity area is also flexible enough, allowing reconfiguration of the table and seats to respond to different activities of the team members. The setup of digital space is illustrated in Figure 3.3.

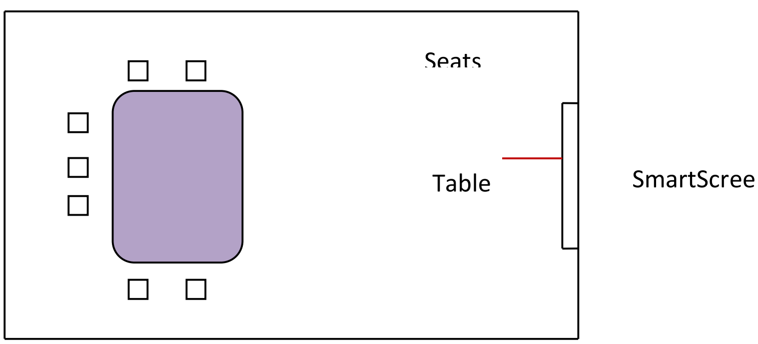


Figure 3.3: Set-up of digital space 3

3.4.2 Study population

The population for this research is any architectural practice where digital information (content) and media support team members' actions and activities in design meetings. Specifically, architectural firms advanced in digital practices (approach to designing where design processes and workflows are driven by data-rich digital information and associated technologies) and support their team meetings with the use of digital spaces constitute the population for this study. Since the study is about design team meetings, all design meetings within which team members interact to review the evolving design in the architectural practice during the period of data collection potentially forms the population for this study.

3.4.3 Sampling and sample size

The study employed purposive sampling strategy where the research subjects and activities to be studied are predefined (Atkinson and Flint, 2001). This approach allows the researcher to choose a case because it illustrates some features or process of interest to the study. Apart from the case reflecting the phenomenon of interest (mediated team meetings), access needed to gather the case study evidence also become critical consideration, as argued by (Yin and Sage, 2003). However, while purposive sampling is employed specifically to obtain appropriate case for the study, (Silverman, 2015) maintains that parameters of the population which the researcher is interested need to be critically taken into consideration to inform the basis of the sample.

The use of purposive sampling has been found to be predominant in qualitative research. The rationale, according to (Guba and Lincon, 1994) stems from the fact that many qualitative researchers concentrate on both the phenomenon and the context where processes being studied are most likely to occur. Consequently, selection of the study case was motivated by two reasons. First, the setting and the case possessing the behaviour of interest or where the phenomenon under consideration is more likely to emerge. Second, accessibility and convenience in obtaining relevant data of interest to answer the research question. To operationalise this, the sample constitute, first, architectural practice whereby its workflows and processes are driven by data-rich digital information and associated technologies; second, design team meetings supported by digital-spaces and third preparedness of the practice to participate in the study.

This research was based on a single case study of a selected architectural practice. A single case has been described by (Yin and Sage, 2003) as a phenomenon embedded in a single social setting which allows an in-depth investigation to be conducted within the context of the study. According to (Yin and Sage, 2003), a single case is appropriate in situations where: 1) the setting of the case provides opportunity for an existing theory to be tested or validated, challenged or extended; *2)* the case has unique characteristics; or 3) there is an opportunity to reveal richer insight into a phenomenon previously inaccessible to empirical investigation. The rationale to adopt a single case architectural practice is mainly informed by the second and third situations above. It is argued that single case study is best suited to dealing in-depth with the messy and fluid nature of the digital space, where trajectory of digital information and media become unpredictable in the interaction process (rationale 2), as well as dynamics on the team's interactions (rationale 3) (Yin and Sage, 2003).

Within this single case architectural practice, design team meetings constitute the sample as the analytic interest of the study focuses on interactions in design team meetings. In this case, the researcher is provided with opportunity to study several contexts within the case or study several different cases in the single firm. Hence, several design meetings nested within the architectural practice are studied to yield adequate data relevant to answer the research question. While the sample encompasses different design meetings supported by digital spaces, the size of the sample is not specified, but is rather driven by reaching data saturation. This is informed by a position of Marshall and Rossman (2006) that sample size in qualitative research is not determined a priori but is dependent on the context.

However, while these rationales support adoption of a single case study, limitations have been raised in connection with this approach. The main argument being that conclusions from a single case study cannot be generalised to a wider population of the study (Leonard-Barton, 1990). Whiles this concern is legitimate, Yin and Sage (2003) maintains that single case study, which is a form of qualitative research within interpretivist tradition, mainly seeks to develop understanding of a phenomenon within the context of its emergence, hence the issue of generalisation cannot be used to discredit findings of single-case. This study aligns to the position maintained by Yin because the results are meant to shed more light on how the design team interact in the fluid and heterogenous digital space to communicate the design and perform a task during the meeting session within the architectural practice studied. A single-case design in qualitative research exist in two forms: holistic single-case and embedded single-case (Yin and Sage, 2003). According to Yin, the variations in single-case is underpinned by the units of analysis of the study. Holistic single-case study examines a single unit of analysis while embedded single-case considers more than one unit of analysis. The embedded single-case is argued (Yin and Sage, 2003) to yield more insight into the phenomenon of interest compared to the holistic type. The premise being that, embedded single-case affords the researcher the opportunity to examine the larger unit of analysis as well as subunits within the context, thus providing more details of the phenomenon and context of its occurrence. For example, in studying a phenomenon of interest the contextual characteristics may also provide an insight in understanding of the research unit. Hence, the subunit analysis, which in this case is the characteristics of the context, is nested into the single case. However, while embedded single-case is argued to yield more insight into the phenomenon, Yin and Sage (2003) cautions against the temptation of over-concentrating on the subunit analysis to the detriment of the larger focus of the study.

To conclude, this study adopted the embedded single-case approach to explore the interactions of team members and technologies (media and content) in the digital space while communicating and developing the evolving design. The premise is that, although the larger unit of analysis centres on interactions in team meetings mediated by digital spaces, features of technologies being relied on to support the team's interactions also stands to provide additional insight as argued in Chapter 2, into the context of these exchanges. Hence, the features of the technology also become a subunit of analysis in addition to the team interactions in the mediated digital space.

3.4.4 Access to the data

Establishing contact with a designer and gaining enough trust for them to become involved with this research was the first stage in gaining access to the data, as the designer is considered a gatekeeper or key informant to the event (Marshall, 1996). The data collected is regarded to be of sensitive nature since it emanates from 'real' projects across the various stages of the design development. Usually, in these phases of the design process, formal and contractual arrangements in connection with data protection and confidentiality as well as third party involvement have been entered into, hence access to meetings and video recording of interactions among team members and media (design information and medium) by a researcher maybe in violation to the legal requirements of the project. Consequently, appointment terms and conditions were discussed between the researcher and representatives of the architectural firm in charge of digital practice (design approach where design processes and workflows are driven by digital information models and associated technologies).

The second stage in gaining access to the data was dependent on the firm having on-going design projects exhibiting characteristics of digital practice to collect data from. Most of the architectural practices contacted were interested in the research, however, the design projects did not fall within the focus of the research, or the firm did not have current projects within the period of the investigation to participate in the research. In some situations, the sensitivity of the project data, coupled with proposed video recording of design team activities were considered a breach to the terms of the project contract, thus were unable to take part in the study.

To develop a rapport and build trust with the architectural practice, I prepared an information sheet detailing the research and specific support required. Specifically, the information sheet described the aim and objectives of the research, the use and storage of the data and provided assurance that the privacy of the team members will always be kept. Apart from this, the information sheet had participant consent section in adherence to ethical practice of research involving human subjects. The information sheet was sent to the key informant of the firm via email and a follow up face-to-face discussions held to clarify outstanding issues and incorporate them into the final version of the form. The information sheet with the consent form component is presented in Appendix (A) of this thesis. The next section describes and discusses the procedures adopted for the data collection.

3.5 Data collection methods deployed

The study employed video-based method as the principal data collection technique to capture fine-grained interactions among the team members and with technologies during the design review meeting session. Additional methods such as participant observation and document analysis were employed to understand the background of the design project as well as the social and material environment of the design meeting. The following sections discuss these methods and justify their appropriateness as tools to gather empirical data for the study.

3.5.1 Video–based method

Video-based method is an approach to data collection where events and activities are recorded as they unfold with little or no interference of the researcher (Heath et al., 2010; Jordan and Henderson, 1995). Video-based method provides opportunity to access rich information on participants' behavior and features of events during the interaction process. These behaviours (talk, body movement, physical action and use of technology) are difficult to capture using interviews or conventional field observations (Jordan and Henderson, 1995; Lehn et al., 2005). According to Jordan and Henderson (1995) while field observation commits to the investigation of social interactions around technologies, standard tools such as field notes, and paper-and-pencil snapshot of complex events are inadequate to track distinct behaviours. They maintain that some behaviours such as manipulative procedures of people navigating virtual objects on screen are difficult to track because of the complexity of such activities. Besides, the problem of where to focus to obtain rich data, which ethnographers often grapple with during observations are resolved using video technology due to its view range capability. Since the study seeks to explore conversations among the team members as well as how they interact with media to perform a specific action, the use of video recording is seen as appropriate.

Using video enables replay and detailed examination of empirical data on rich interactions between the team members and with technologies in the work setting. The opportunity for multiple viewing and listening enable researchers to immerse themselves into the data, thereby identifying relevant categories and instances required to inform analysis and presentation of the video data. For example, through repeated viewing, some important aspects of the phenomenon previously unnoticed are revealed to enrich the results of the study. Besides, motion of video records can be adjusted during play mode to reveal hidden behaviours of people in the interaction process. The opportunity to replay the video in an adjustable speed is seen as essential to facilitate the analysis of interactions among the team members and with technologies since focus of the study dwells mainly on fine details of participants' actions and activities to yield in-depth understanding on social interactions around technologies in a heterogenous and fluid digital space.

Additionally, video data affords opportunity to share, review, discuss and debate data in its natural state with others since video records are readily available as a common resource. This collaborative practice enables people aligned to the research to participate in the analysis of the video data by examining emergence and sequences of actions in relation to circumstances of their occurrence, and explore multiple perspectives (Jordan and Henderson, 1995; Tutt and Hindmarsh, 2011). This aspect of the video-based method is considered relevant to the current study since different perspectives are required to enrich modification of the mediated interaction analytic coding scheme adapted to code the collection of instances in the video transcript.

Lastly, video method has a wide applicability in the study of social interactions around technologies in the work setting. Similar studies that have investigated actions and activities of people around technologies in natural settings have used video recording as the primary mode to capture instances of interactions (Liu, 2016; Maftei and Harty, 2012; Liston, 2009; Tutt et al., 2013; Tory et al., 2008). For example, Tutt et al. (2013) relied on video technology to investigate how participants in design teams use a story to support the navigable space of the virtual reality (VR) model which the clients experience in the CAVE technology. This required that instances of design decisions in the VR model in relation to how the design team negotiate to modify or showcase aspects of the design be captured to support the analysis. Similarly, Liston (2009) employed video as the principal data collection technique to obtain fine-grained data on how people use media and communicate among themselves to understand dynamics of project team meetings in AEC project context. These examples provide evidence to support how widespread video technology is employed to obtain empirical data on how the social, the material and technology are brought together through interactions during team activities to accomplish a goal. Hence, since the purpose of this study aligns with social interactions mediated by technologies in work settings, the decision to use video as the main data collection is deemed as appropriate.

At the same time, certain limitations of the video-based method include 'camera effect', or how people behave in the presence of a camera. Jordan and Henderson (1995) observe that people engaged in interactions in natural settings become alarmed with the presence of a video recording camera within their work environment. Hence, the participants tend to modify their behaviour whenever their actions and activities are recorded. Although this tendency may affect the quality of data, the authors also argue that people over time get accustomed to the camera and assume their normal behaviour as the interaction progresses and they become consumed in their task. Moreover, the degree to which people's behaviour are influenced by the camera is lessened when the presence of the operator is removed from the camera position. Hence, according to Jordan and Henderson (1995) researchers and camera operatives need to position themselves away from the camera to address the influence of camera on the participants behaviours. What this implies is that setup of the video camera needs to be done earlier prior to the team's activities.

Another potential limitation of video-based methods as raised by Jordan and Henderson (1995) is camera operator's decision on what to include or exclude from the camera view range. The adjustments on a camera's settings in terms of viewing angle and audio level influences the kind of video data gathered one stands to obtain. To overcome the problem of leaving out important information due to camera settings, Jordan and Henderson (1995) provide some suggestions. First, video-based researchers need to supplement their video data with field notes to clarify issues not captured by the camera. Second, multiple cameras and audio recordings need to be employed where necessary to capture instances of interactions from different dimensions to enrich the video data.

Consistent with video-based Interaction Analysis principles and coupled with the recommendations to overcome the above limitations, this study supplemented the video recordings with ethnographic fieldwork (participant observation) to enhance the quality of the video data. The next section provides elaboration on the fieldwork.

3.5.2 Participant observation

The study employed ethnographic fieldwork and participant observation to supplement the video-based data collection. Ethnographic fieldwork is considered an approach where the researcher prior to and during video recording of interactions visits the setting of the study and familiarise with its characteristics as well as the activities performed. The aim of ethnographic fieldwork is to enable the researcher to understand the setting and inform the logistical arrangements in terms of video equipment and sound recorders as well as setup of the camera, since important information on sequences of interactions are identified during this process (Jordan and Henderson, 1995). According to Jordan and Henderson (1995), ethnographic fieldwork mainly involves participant observation, informal interview as well as collection and analysis of artifacts and documents. In this instance, participant observation was carried out during the field work mainly to obtain first-hand information on interactions within the context of their emergence.

Participant observation is a form of observation where the researcher directly participates in the activity without interfering with the interaction process. In this case the role of the researcher is to make notes of important developments. For example, Heath et al. (2010) observe that researchers often document unusual events as they arise during the interaction, as well as tasks and activities performed. These records provide useful information to facilitate the main video analysis since specific areas of interest in the video recording are identified.

The rationale of employing participant observation is consistent with the IA methodological orientation underpinning collection and analysis of the empirical data. Interaction Analytic method considers participant observation as one of the key ways of overcoming limitations in the video data because of camera effect and impositions of the camera operator. Moreover, interaction analysis researchers often combine video data with field notes to aid the analysis of the data (Liston, 2009; Tory et al., 2008). How participant observation was carried out is presented in the proceeding section.

3.6 Data collection procedures

This section discusses the procedures employed to obtain the empirical data for the analysis. The section first looks at collection of the video data and then considers the field notes.

3.6.1 Collecting the video data

The study video and audio recorded five design team meetings held at three different digital spaces in the architectural firm across five months, between January 2018 and May 2018. These design meetings involved different in-house design teams engaged in different design projects. The participants were mainly architects and structural designers in the architectural practice. The corpus of data spanning over 11 hours of video recordings of team interactions were captured using two video cameras and an audio recorder. The video cameras were fixed on tripods and placed at different locations to capture different aspects of the team's interactions. One of the cameras was focused to capture interactions among the team members in the activity area while the other concentrated on the screen activities with regards to what the participants were looking at and pointed to during discussions. This move was to enable the researcher account for the ongoing and situated use of the technology (media and content) while communicating to develop the evolving design. The audio-recorder was placed on the table (working surface) where participants were to record the verbal conversations. The decision to use the audio-recorder alongside the video cameras was to overcome poor quality of the camera and ensure that rich conversations around the technologies are obtained to facilitate the analysis. Summary of the details of collecting the video data is presented in Table 3.1

The cameras were setup prior to conduction of the meeting. The issues involved in setting up the camera and the necessary precautions in terms of view settings were facilitated by the initial ethnographic field observations and meetings held with the gatekeepers. During these initial visits, issues on equipment setup were thoroughly discussed.

Prior to recording the meeting events, the participants gave their informed consent by appending their signature on the consent form (see Appendix A).

Table 3.1 Summary of collecting the video data in digitally mediated design meetings

Date of design review session	Duration (hours: minutes) and scope of session	Number of participants	Participants' roles in the design project	Video-audio set up	Medium / information representation used
21/01/2018	02:15- Design review of multi-infrastructure building project (design development stage)	5	Design team: - Architects	2 fixed cameras mounted on tripod (placed at opposite corners of the BIMSpace meeting room) for viewing activity space and screen area	BIMSpace, virtual walkthrough (VR) model; Enscape plug-in Revit architectural application; 3D CAD renderings; 2D CAD views

21/01/2018	02:30- Review of multi-complex housing design project (design development stage)	4	Design team: -architects	2 fixed cameras mounted on tripod (placed at opposite corners of the meeting room) for viewing activity space and screen area	-Large wall display screen virtual walkthrough (VR) model; 3D CAD renderings; Enscape plug-in Revit architectural application; -2D CAD detail views, mobile device-tablets
24/01/2018	02:05- Review of ongoing design project (construction stage)	5	Design team: -Architects -Structural designers	1 fixed camera mounted on tripod (placed in the left corner of the meeting room)	-Large wall-display screen; -3D CAD renderings; -Mobile Device-Smart phones and Tablets
24/03/2018	02:50- Review of walkway design project (conceptual design stage)	7	Design team: - Architects - Structural designers	2 fixed cameras mounted on tripod (placed at opposite corners of the BIMSpace-meeting room) for viewing activity space and screen area	Interactive/ SMART screen, -3D CAD rendering; -2D CAD views, 2D paper detail views, Multi-media (Video) version of 3D CAD rendering

24/05/2018	02:15- Review of multi-complex housing design project	3	Design team: - Architects - Structural designers	2 fixed cameras mounted on tripod (placed at opposite corners of the meeting room) for viewing activity space and screen area	-Large wall display screen virtual walkthrough (VR) model; 3D CAD renderings; Enscape plug-in Revit architectural application; -2D CAD detail views, mobile device-tablets

*Source: Author's fieldwork (2018)

3.6.2 Ethnographic fieldwork and observing the meeting session

Ethnographic fieldwork was carried out prior to the main video recording exercise. The purpose of the field work was to familiarise with the setting (digital spaces) and its operation. Two field visits took place between November 2017 and May 2018, two months before the main video collection. The fieldwork was used to discuss equipment setup and background information on on-going design projects. For instance, in one of these encounters, the digital practice team of the firm introduced the researcher to the digital space 1 and how it operates. Additional information on setup of the digital space 1 in the form of leaflet was obtained to enhance understanding of its operation.

Fieldnotes were also used to document and further complement interesting segments in the video data, such as where the team members resorted to use sketches, personal mobile devices and traditional paper drawings to support their activities. This was consistent with the principles of IA methodological orientation to situate people's actions and activities in the context of their occurrence. Hence, the researcher used this occasion to understand background of the interactions and aid preparation of the content log (summary of key events occurred in the meeting session). The details of the content log are presented in section 3.7.1. The next section discusses how analysis of the video data was carried out to obtain the results of the study.

3.7 Data analysis approach: Thematic analysis

Consistent with methodological principles of video-based Interaction Analysis research (IA), the process of operationalising the empirical data in the study for addressing the research objectives draws on a thematic analysis informed by key themes in the conceptual model. Specifically, the analysis is based on the overarching themes including communication instances and interactions in relation to digital media (medium and information representation).

Thematic analysis is described as an approach of analysing qualitative data where themes (categories) within the data corpus are identified, analysed and presented in a comprehensive manner to yield insightful findings relevant to answering the research question (Braun and Clarke, 2006). The method focuses on exploring categories significant to understanding the phenomenon under investigation (Braun and Clarke, 2006). Firstly, it allows a comprehensive multi-step iterative exploration to identify relevant categories emerging from the empirical data (Braun and Clarke, 2006), whereby both the phenomenon under investigation and context of its emergence are accounted for. Secondly, it aligns with Interaction Analysis research tradition where flexibility is introduced in the analytic process, allowing both initial themes mobilised from the literature and themes emerging from the empirical material to shape the analysis (Boyatzis, 1998). In other words, while the predefined categories, which are often organised in models or coding schemes, set the initial stage to explore themes in the data corpus, the final themes relevant to developing understanding into the phenomenon are informed by the categories induced in the empirical data. Thirdly, thematic analysis follows an iterative approach to obtain the results worth addressing the underlying concern of the study (Patton, 1990). This allows flexibility into the analysis process by enabling researchers to extensively revisit the data as necessary to enrich the analysis. Lastly, similar studies exploring social interactions around technologies at the micro level of interaction employed thematic analysis to analyse the corpus of video data. For example, Maftei (2015) in her study on interactions of team members and how they orient to the technology in a design review session used thematic analysis to analyse her video data based on its appropriateness in yielding relevant insight into the phenomenon. Consequently, this study employed thematic analysis to aid exploration of conversations around technologies (media and content) in the digital space while team members communicate the design and perform a task during design meetings in the architectural design practice. Basically, the thematic analysis used for this study follows the analytic procedures set out by (Braun and Clarke, 2006) (see Figure 3.4).

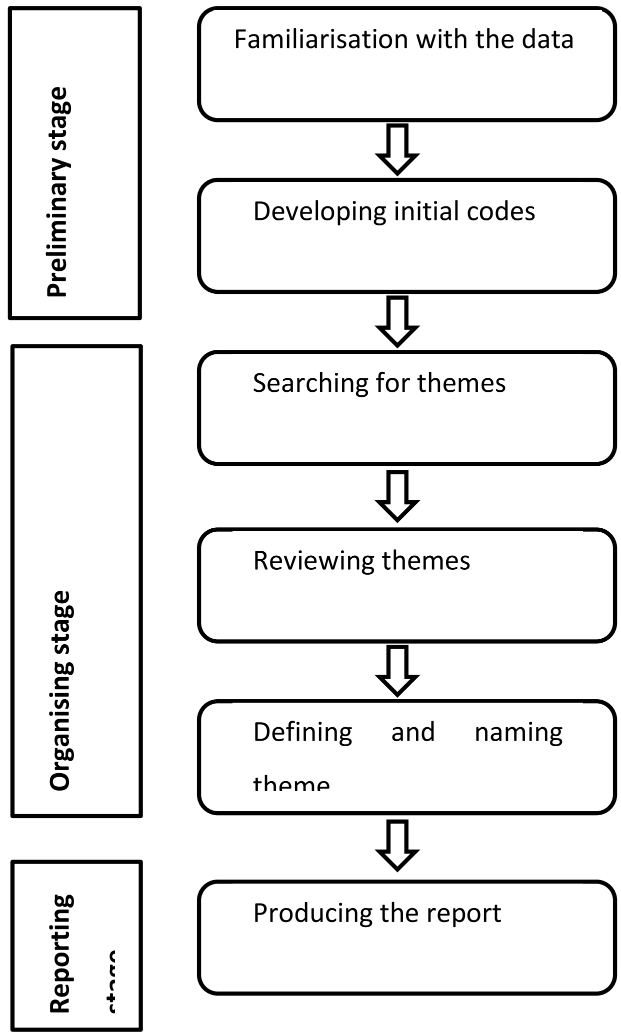


Figure 3.4: Phases of thematic analysis (adapted from Braun and Clarke, 2006)

According to Braun and Clarke (2006), phase one of the analytic process mainly enables the researcher to develop awareness of the events and sequences in the data corpus. It involves:

- Familiarising with the data corpus through reviewing and transcribing the data; continuous reviewing and noting down of initial ideas;
- Generating initial codes, which also includes applying initial coding scheme, is devoted to coding interesting segments of the data systematically across the entire data set and collect instances of data relevant to each code.

In phase two, which is organising stage, coded data is organised into themes by:

- Searching for themes and realigning or combing codes into potential themes or subthemes and gathering all relevant to each potential theme or category;
- Reviewing themes by checking if the named themes reflect the underlying coded dataset;
- Defining and naming themes by iteratively analysing the data corpus to refine the appropriateness of each theme, ensuring that the overall story that the analysis tells is attained.

The last phase of the thematic analysis process which concentrates on reporting or presenting the findings in terms of a story line basically provides opportunity for selecting compelling examples from the collected instances to illustrate the themes (Braun and Clarke, 2006). The illustrative materials may take the form of fragments from the video transcript, snapshots or tables depending on the focus of the study. The proceeding sections discuss the thematic analysis process within the methodological principles of IA.

3.7.1 Preliminary phase of the video data analysis

3.7.1.1 Content log

Content log was made after each video recording to document important events for future use. Content log is described as a summary record of events captured on the videotape to inform the main analysis of the video data (Jordan and Henderson, 1995). It mainly consists of headings indicating identifying information such as date in which the recording was done, period and duration of the event as well as the place where the event took place. This is followed by summary of the important information observed in the meeting proceedings relevant to the analytic interest of the study. The content log is basically an expanded version of the field notes, since important events that are likely to inform later analysis of the video data are recorded in the field book.

Content log provides a quick overview of the data corpus allowing easy tracking of segments and issues in the video data and informs the transcription of interesting segments in video data (Braun and Clarke, 2006; Heath et al., 2010). Maintaining content log conforms to the analytic principles of Interaction Analysis (IA) methodological orientation since it preserves the integrity of events as observed in the meeting. The content log was done using the Transana 3.21 professional video analysis software. For each video episode the researcher maintained a content log capturing interesting segments and their sequence of emergence. For example, information on when and how personal or informal digital media such as tablets and mobile devices entered the interaction process during the meeting session was documented as important segments to inform the main video analysis. This stems from the view of digital spaces as fluid and heterogenous where different media can be brought into the interaction process to structure the conversations and participation of the team members.

3.7.1.2 Ttranscribing the video data

Transcription is a method of representing participants' activities during the interaction process as captured in video data. According to Heath et al. (2010) transcription also serves as a resource to inform observations and familiarisation of the actions undertaken by the participants. The actions and activities worth representing in transcription as argued by Jordan and Henderson (1995) depend on analytic interest of the study. In line with this position, this study transcribed both verbal utterances of participants as well as nonverbal behaviours, such as gaze, gestures, object manipulations and interaction technology (media and content).

However, in the case of participants' talk, the researcher did not transcribe speech acts, but only the utterance (nature of talk) since this was not relevant to overarching concern of the study. In terms of non-verbal action, the transcript did not cover body language and facial cues since focus of investigation of the study centred mainly on actions with direct reference to the information representation and display medium.

The video data was transcribed in relation to the common units of analysis (i.e., utterances or speaker turns) often employed by interaction analysis researchers (Goffman, 1981). Prior to transcribing the video data, the researcher reviewed the data corpus to inform the transcription process as recommended by Heath et al. (2010). The rationale for repeated review was to enable the researcher develop depth of insight into interesting segments of the data corpus and make decisions regarding aspects of the data worth transcribing. Upon continual review of the video data, I transcribed the entire stretch of the video data (episodes) recorded from the meeting sessions. The decision to transcribe the full duration of the meeting session was due to compelling revelations of rich interactions emanated during the meeting process.

The video transcription was carried out using Transana Professional 3.21 video analysis software (Figure 3.4). Transana Professional 3.21 is used in qualitative video-based studies to manage and organise the transcription and coding process because of its capabilities to play back the video, transcribe and synchronize the transcript with the video data (Fassnacht and Kose, 2007; Liston, 2009). The software works by importing video data and allowing users to create series, e.g., separate observations, and associate multiple video (episodes) and transcripts to those series. It provides an interface to transcribe as the video plays and insert time stamps to synchronize the transcription with the video. Hence, users can create collections and store clips in the collections, e.g., collection of clips showing a specific behaviour in the conversation or interaction among the team members or with the media (medium/content).

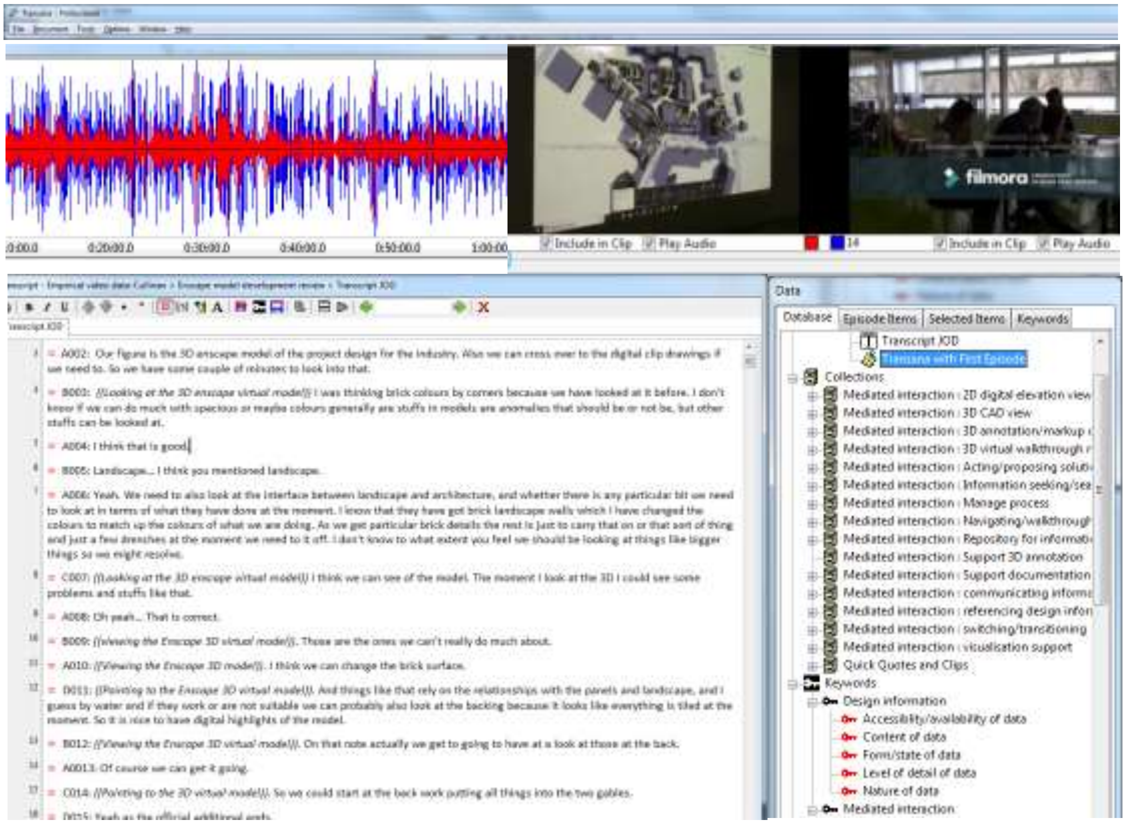


Figure 3.5: A screenshot of the Transana 3.21 professional video analysis software. Users can import video data, create series (separate observations and multiple episodes). The interface of the software allows users to transcribe the video data, create collection of instances reflecting the overarching themes as well as assign codes to clips stored in the collections.

To ease the transcription process, the files from the two video cameras were combined into a single file using an online Freemaker Video Convertor software and subsequently loaded into the Transana Professional 3.21 video transcription software. After the initial iterative review of the video recording to familiarise and identify interesting fragments in the recording worth transcribing, the transcript was segmented whenever a new speaker took the turn in the review meeting along the verbal utterances and non-verbal actions in relation to the use of the media.

Each turn represented a speaking, or non-speaking act of interaction. On the premise of the analytic foci of the study, speech acts were not included in the segmentation criteria (Goffman, 1981). I labelled each segment with an identifier, 'A-J' to refer to a specific meeting participant and numbered it incrementally with three-digit number (e.g., 001). In the case of non-speaking behaviours, I used double-parentheses and italics to highlight them during the transcription process. The researcher used notation symbols below to highlight the non-speaking turns:

- "X": segment involving interaction with media. This is meant to identify and distinguish a discreet act of a team member in the interaction process which is directed towards the media in the event of producing the interaction. This segmentation enables adequate account to be given on how media is incorporated in the entire interaction process.
- I appended to these labels a three-digit number representing the sequence of the segment in the meeting data, for example, "A001", "B002", "A003", and so on. These characterisations and use of notation symbols were informed by Jefferson's Orthogonal System of transcribing conversations in interaction (Jefferson, 1984), and also as employed in similar studies (Liston, 2009). The next section discusses the development of the coding scheme for detailed analysis of the transcribed data.

3.7.1.3 Developing the coding scheme and coding the video transcript

This section discusses the development of the coding scheme for the transcribed data. Following the principles of Interaction Analysis (IA) research techniques and thematic analysis processes, a modified mediated interaction analytic (MIA) coding scheme (Liston, 2009) was used to code the transcribed video data. The MIA coding scheme was modified for two reasons. First, this study focuses on how the team members converse around technologies (media and content) within a heterogeneous and malleable digital space while communicating the design and performing a task around. Second, other dimensions of interaction such as task performance, capabilities of information content and media, as well as their situated use in the team's interaction process were incorporated. Hence, high level concepts in relation to design information captured in MIA such as grounding, decision making, and acting were disintegrated into lower level categories to provide relevant insight into interactions with media or behaviour of team members. For example, the construct "grounding" relates to categories such as describing and explaining whiles decision-making relates to evaluating and predicting design information.

In contrast to Liston, where the coding scheme was used to quantify interaction and perform statistical analysis of time spent in relation to the categories, I used the categories to describe and explicate in fine detail, how the team members communicated the design and performed task while interacting with features of the digital space (content and media) within their local context. The modified MIA coding scheme applied to the video transcript is presented in Table 3.2.

Further, the predefined coding scheme was modified iteratively as the process of data collection progresses to respond to emerging categories in the empirical data. The revision was carried out by first applying the initial coding scheme to a ten-minute segment of the data recorded in the first design meeting (see Table 3.2).

Table 3.2 Sample of the raw coded data in Transana spreadsheet

Text	Communicative act	Task type	Purpose of media use	Media type	Content	Interactivity	Accessibility

A001: That work. It looks like seem so really. I think that, that elevation probably is a sign. This probably is a marble work.	describing	N/A	Support visualisation; data repository	Enscape plugin Revit architect ure; Wall display	Virtual reality (VR) model	Viewing, pointing/g esturing	shared
X002: ((Viewing the VR model))	N/A	N/A	Support visualisation	Enscape plugin Revit architect ure; Wall display	VR model	viewing	shared
D003: Is it probably still possible for redesign this section?	Gives suggestion Evaluating	N/A	Information resource; support visualisation	Enscape plugin Revit architect ure; Wall display	VR model	Viewing, Pointing/g esturing	shared
C004: Yes. Yes.	agrees	N/A	N/A	N/A	VR model	Viewing	shared
D005: *((Pointing to the 3D enscape virtual model*)). Is there better options to tackle that?	Evaluating	N/A	Information resource; support visualisation	Enscape plugin Revit architect ure; Wall display	VR model	Viewing Gesturing/ pointing	shared
"C006: There are much bigger questions there	Raising concerns evaluating	N/A	Information resource	Enscape plugin Revit	VR model	Viewing	shared

which is that they want clearer idea. But it is only looking here help looking at this portion the way these party walls work.				architecture; Wall display			
D007: Should we look at the elevation of it as well?	Gives suggestion Evaluating						
X008: *((switching to generate and display 2D elevation view and viewing))*	N/A	Generating	Support authoring content; Manage process; Information resource	Enscape plugin Revit architecture; Wall display	Digital 2D elevation	viewing	shared
"B009: Oh! We have blank corners anyway just to the stairwell.	Raising concerns- Evaluating	N/A	Information resource; support visualisation	Enscape plugin Revit architecture; Wall display	Digital 2D elevation	Viewing; gesturing/ pointing	shared
X010: ((Viewing, and creating a view of the area under consideration))	N/A	Generating	Support authoring content;	Enscape plugin Revit architecture; Wall display	Digital 2D elevation	viewing	shared

D011: And it seems to be strange just to punch a hole rather than two slots.	Raising concern Evaluating	N/A	Information resource; support visualisation	Enscape plugin Revit architecture; Wall display	Digital 2D elevation	viewing	shared

*Source: Field data (2018); *Each segment in the raw data, e.g., the segment with ID "A001", includes text, and keyword assignment for each analytic unit.*

The rationale to code a sample of the video data was to assess suitability of the coding categories and whether the analytic scheme provided adequate insight on interactions with media (content and medium) or behaviour of the team. Consequently, I either (a) redefined a coding category, or (b) added or removed a category to fine-tune the evolving analytic scheme. For example, the initial coding did not capture activity such as authoring, however, upon re-examining the video transcript, authoring was included in the coding scheme to reflect reality of the data within the context of its emergence. Second, after subjecting the coding scheme to this initial process, two colleagues researching into similar areas of study, together with the researcher, jointly coded the sampled data in Transana professional 3.21 spreadsheet using modified version of the scheme to inject rigour the analytic process (Woods and Fassnacht, 2007). The process of adding, removing, or reclassifying coding categories was done repeatedly to yield an appropriate coding scheme reflecting concepts emanating from the empirical material. Consistent with the process of coding in IA and thematic analysis whereby coding categories are developed into potential themes, I searched through generated codes, realigned and combined codes to provide key analytic themes appropriate to inform the overall story as revealed by the analysis.

The final version of the analytic coding scheme is presented in Table 3.3.

Table 3.3 Mediated interaction coding scheme

Team interaction perspective		**Media used in practice perspective**					
				Media		**Content**	
Communicative act	**Task type**	**Interactivity (media/content)**	**Purpose of use of media**	**Type of media**	**Feature**	**Type/form of content**	**Feature**
Exchanging	Authoring (generating/sketching)	Viewing	Support visualisation	Enscape plugin Revit architecture application	Large screen	Virtual reality (VR) model	Real-time representation
Describing	Proposing alternative solutions	Navigating	Support information seeking/searching	Wall display	Smart screen	3D CAD renderings	Static representation
Explaining		Annotating/Mark-up	Information resource	PowerPoint	Single data display	2D CAD detail views	Realism

Evaluating		Gesturing	Support annotation	SmartScreen display	Multiple data display		Navigable/ Manipulations/interactive
Predicting			Support authoring	Mobile device (tablet/smart phone)	Virtual walkthrough		mark-up
			Managing process	paper	authoring content		Virtual walkthrough
					Annotation/ mark-up		Renderings
					Information storage		Images

*Adapted and modified from Liston (2009.

Coding: Coding of the full transcribed video data was carried out using the developed coding scheme. This was accomplished through the following processes:

- Creating thematic collections of instances to reflect categories of specific activities or actions emerging from the transcript. In this case, the key themes modified in the analytic coding scheme such as communication instances, task performance and use of media were created as thematic collections to store instances of behaviours through the Transana professional 3.21 video analysis software.
- Instances within the segments reflecting specific thematic categories were selected and placed within their respective collections in the Transana analytic database.

- Since existed in the instances of behaviours of members interactions collected, creation of additional collections as subthemes within the broad thematic collections (communication instances, task performance and use of media) were pursued vigorously throughout the coding process to ensure instances stored in collections reflected the specific behaviour category. For example, verbal utterances meant to provide description about design elements and other spatial information were separated and stored in the subtheme collection labelled describing.
- Through the process of iterative review of the segments, quotes and clips (behavioural instances in the transcript) were selected and placed within their respective thematic collections. These quotes were coded accordingly using the codes developed in the mediated interaction coding scheme. The process of coding instances of behaviours in the thematic collections was carried out throughout the data collection exercise until meaningful segments relevant in creating the story of how participants interact in the various team members was revealed.
- Finally, since participants' behaviours in most were embedded with multiple functions, instances of such behaviours were stored a number of times different thematic collections to ensure other dimensions of the behaviour are catered for in the analysis. For example, a team member explaining rationale underlying a suggestion references content of design via nonverbal behaviour such as gesturing or manipulating the design representation displayed on screen. In such situations, the segment attracts multiple interpretations comprising communication instance (explaining), interacting with media (gesturing/pointing) and purpose of use of media (information resource).

The assignment of codes to collection of instances was further reviewed to ensure that thematic collections accurately reflected the required behaviours. The next section discusses how the coded data in the collections were organised and further explored using keyword (code) searches to examine the interplays of the various themes and subthemes around the range of activities ensuing among the team members during the meeting session.

3.7.2 Organising stage

This process of repeated examination of the video data, combined with organising the insights around the iteration of categories through to reaching saturation of observations in the data, resulted in establishing the final analytical themes.

3.7.2.1 Detailed analysis of collections of instances organised around the themes

This phase of the analysis process centred on examining collection of instances around the coded categories and sub-categories of the team's interactional exchanges during the meeting session. Mainly, specific attention was drawn to how the empirical data reveals variations in the instances of behaviours around the coded categories as well as the linkages connecting these categories and sub-categories of communication instances, task performed and interaction with the technologies. This examination to explore how the social, material and the technologies come together in and through interaction to communicate the design and accomplish a task was accomplished through the Transana professional 3.21 video analysis package. Specifically, the analytic codes (keywords) assigned to the collection of instances were used to explore how the communicative acts, tasks performed and interactions with the technology played out during the meeting session. This process was done repeatedly throughout the data corpus to refine the specifics of each theme and the overall storyline that analysis reveals. The next section presents how the refined analytic categories obtained in the analysis were presented in the thesis.

3.7.3 Producing the report

Presentation of results obtained from the video data climaxed the data analysis process of the study. In line with thematic analysis method, where illustrations of instances of behaviours describing a category in a data corpus are displayed, the researcher used a variety of ways to exemplify the key categories of the team's communication instances, task performance and interaction with media and information content during the meeting sessions. The illustrations included fragments from the transcribed data, snapshots of participants interacting among themselves as well as with media and content of design information. The essence of illustrating the analytic categories was to provide narrative description of their sequences of emergence in relation to the media and other actions. This way of presenting the findings was to ensure that the fine-details of participants' actions and activities critical to developing comprehensive understanding of workflows in the design team within digital space. The selection of the excerpts and still images was done based on their appropriateness in revealing rich insight about the underlying behaviour. In this regard, the video data was reviewed severally to enable choice of best examples to tell the story of the analysis. The visuals of participants interactions selected for the report were captured from the video files in the Transana database and stored alongside the instances of interactional acts in the named thematic/sub-thematic collections. The still images captured to present data in the thesis were further edited using Photoshop version 2020. The editing mainly concentrated on blurring the image quality to hide identity of participants captured in the video. In order to address the issue of anonymity in this study, the participants were only referred to by alphabetical letters and not by their names in presenting the video data in this thesis.

In addition to fragments and still images, the study used tables (matrix display) to present data in the thesis. Specifically, the tables were employed to present the abstract categories/themes of communication instances, task performance and use of technologies (media and information content). The display of key themes and subthemes emerging from participants' interactions around technologies in the digital space via tables (matrix display) was also used to highlight the interplays (how the conversations, physical actions and interaction with media and content come together in interaction) of the various types of interactions observed in the video data. The decision to combine these range of illustrations to present the results in the thesis ensured that key actions and activities with which design team members relied on to communicate the design and perform a task, and their situated and emergent nature are adequately communicated to yield in-depth understanding about how interaction occurs in the digital space.

3.8. Research ethics and confidentiality

This PhD research was conducted in compliance with the University of Reading ethical procedures in relation to participants' consent, confidentiality and data protection. The ethics approval process was approved by School of the Built Environment in line with regulations underpinning scientific investigations involving human subjects. The highlights the informed consent, data management and confidentiality issues employed in the conduction of this study.

3.8.1 Informed consent

Prior to data collection, the participants were acquainted with the research project, were presented an outline of the study (Appendix A) and gave their informed consent to participate voluntarily. Privacy and anonymity of participants and teams' identities were preserved in the thesis.

3.8.2 Data management

Both the video data, and the audio recordings of design meeting sessions, as well as the related transcripts and snapshots of images were kept securely on the University network. Copies of the data were kept locked at all times. The data was not circulated outside of the research group.

3.8.3 Confidentiality

The empirical case examined in this study are a real-life construction design projects which, moreover, were ongoing at the time the research was being conducted. These circumstances specifically required strict confidentiality to be met throughout the study. Hence, project related issues including contracts and roles of participants were not included in the study. Individuals were described only as participants or designers in the project, and the snapshot images used in the thesis for presenting instances of the video data were carefully selected to comply with anonymising the participants' figure.

3.9 Limitations of the study

Although the research was built on the opportune availability to access insights into how the design team members interact with and around technologies in digital spaces to review designs of real-life ongoing design projects, access to rich data was generally a challenge, thus limiting the amount and richness of data needed to shed light on the phenomenon. This is was a result of the video-based technique employed to record interactions of team members with each other and with technologies (information content and media). In some situations, design meetings which were considered sensitive, for example, designer-client meetings were not allowed to be video recorded due to legal issues involving third party involvement. However, access to data on designer-client interactions around the array of technologies in the digital could have provided additional dimension to how the professionals and non-professionals also interact to communicate the design and perform task in the heterogeneous ad fluid digital space during the meeting session.

3.10 Summary of the chapter

This chapter presented the methodological orientation and research design used in this study. The research design was developed to ensure the fulfilment of the study objectives, mainly to explore the interaction of design team members with and around technologies in digital spaces to communicate the design and perform a task during design meetings in a selected architectural practice. In addition, the methodological orientation and related methods were developed to gather rich empirical video data to yield new insight into team interactions in a heterogeneous and fluid digital space. Ultimately, this insight could help researchers and practitioners in collaborative design mediated by technologies to understand how to plan collaborative design works in environments considered fluid and heterogeneous and appreciate how varying technologies- formal and informal (personal) are brought together to accomplish a task during design team meetings. This chapter also discussed the data collection approach for this study, including the use of video-based method, ethnographic field study (participant observation), single case study and data analysis techniques. The next chapter presents the results of the data analysis and discusses how these results were systematically employed to achieve the research objectives and provide a comprehensive understanding into the workflows of the team members in digital spaces during design meetings.

Chapter 4 : Results and Analysis

4.1 Introduction

This chapter analyses video data and observation gathered on interactions of design team members during design meetings mediated by digital media. Based on the assumption that design review meetings encompass undertaking of variety of actions and activities mediated by heterogenous and dynamic technological settings within the context of practice, the motivation for examining the empirical material focuses on understanding how the design team members communicate the design and perform task through the support of media (information representation and display medium during an architectural design meeting session. Hence, the chapter explicates how several forms of interactions, both verbal and non-verbal in relation to the digital space, are employed to accomplish the design review task. The chapter begins with the background information of the empirical data to situate the analysis in context along key themes of the analytic scheme/model: communicating design information, interacting with media and performing design task. The following sections develop detailed analysis of these aspects by focusing separately on each theme through close examination of situated interactions occurring in the digitally enabled design review meetings.

4.2 Background of empirical data

The context within which human action and practices evolve shed light in understanding their situated meaning since circumstances underlining their emergence are dynamic (Jordan and Henderson, 1995). This means the background of empirical data places the study into right context, thereby contributing to better understanding of workflows in the design team. This study sought to position analysis of the data within local context of its emergence.

Specifically, the study highlights the team and its composition, the task performed and characteristics of the material environment.

This video data was recorded from design review sessions conducted in varying meeting rooms mediated by different media such as large wall display, multi-projector displays (BIMspace) and SmartScreen. The digital space with range of other media, including mobile devices (tablets and smart phones), digital technology application (Enscape plug-in Revit Architecture), as well as information representations including virtual reality (VR) models, and BIM models (3D CAD rendered models, 2D digital detailed drawings, 2D digital photos, multimedia video file), 2D traditional paper detailed drawing and sketches. The design teams observed in this video episodes were in-house multi-disciplinary design project teams. The participants have worked together as a team on several design projects embarked by the firm, hence familiar with each other. The design teams were embarking on a number of design projects including multi-housing design project, and aerial walkway projects. The multi-housing design projects were at the design development stage while the aerial walkway design project was at the conceptual design phase. As part of their schedules, the team reviewed both VR models and BIM models (3D CAD renderings) to identify design issues, review decisions and propose solutions to address identified problems.

The subsequent sections provide detailed analysis of the dynamics of exchanges of the design team that ensue in the meeting sessions.

4.3 Mobilisation of media to support interactions in the design team

This section analysis the various information representations and display medium mobilised to support the communications and tasks of the team. Drawing on practice lens of technology use, the section presents salient features of the information representation and display medium utilised as well as their purpose of use during the meeting sessions.

4.3.1 Features of media

The study sought to identify and categorise salient features of the media (information representation and display medium) utilised to mediate the actions and tasks of the design team during the meeting sessions. The essence of this categorisation was to provide a detailed account of when, how and why specific features of the media were incorporated in practice to shape the experiences of participants and facilitate accomplishment of specific design tasks. The analysis categorised information representation into three distinct types, including virtual reality (VR) models, three-dimensional computer aided design (3D CAD) renderings, and two-dimensional drawings (2D CAD views and sketches). However, in the case of the display medium, the study classified it into four types (i.e., Wall display/ Multiple-projector screens, SmartScreen, Mobile device and Paper medium). The classification was done based on the utmost importance of the feature in supporting the task of the team and the extent to which it shaped the dynamic exchanges (i.e., encouraged adequate involvement of participants) of the team members (see Table 4.1).

Table 4.1. Categories of information representations by their features along with brief examples

Media category	Types mobilised	Salient features used	Consequence
Information representation	Virtual Reality (VR) models	Virtual walkthrough, Navigable, Photorealism, Mark-up, Manipulative,	Allowed the function, performance and aesthetic aspects of interior and exterior elements of the design to be explained and interrogated; Enables participants to virtually walkthrough the model and engage with specific aspect of the design content. Helped the team to navigate and manipulate elements of the design to obtain better perspective relevant

			content. Aided the team members to mark-up and add comments in real-life.
	3D CAD renderings	Manipulative, Realism/Renderings, Static / Still images	Enable the function, performance and aesthetic aspects of design elements to be explained and interrogated; Allows participants to access relevant aspects of the design.
	2D views (CAD views and paper and pen sketches)	Mark-up, Manipulative, Shaded, 2D, interactive (modified)	Allows participants to explain layout details of the design, and also verify specific aspects of the design
	Wall display/ Multiple-projector screens	Large screen, Non-interactive interface, Shared	Displays large amount of information, promotes and sustains group discussion

			around design information, limits control over manipulation of design information on-screen, reduces dynamic exchanges in the team
Display medium	SmartScreen	Large screen, Touch-sensitive interface, Shared	Sustains group discussions about design information, displays large amount of information, promotes gestural actions on-screen, allows individual members manipulative control over information content, stimulates and sustains dynamic exchanges among the team members

	Mobile device (tablets/smartphones)	Small screen, Touch sensitive interface, Mobile, Private	Limits access to information, enables individuals' manipulative control over design information, reduces dynamic exchanges in the team
	Paper	Flexible, mobile, Interactive, Small interface	Allows quick representation of design ideas, stimulates dynamic exchanges among the team, limits discussions about design information to smaller number of team members.

Source: Author's field work (video data), 2018)

The size, interactivity and ownership/availability characteristics of the medium were observed to shape differently the involvement of participants in team's exchanges and engagement with design content. From the analysis, large screen sizes encouraged individual members to participate in discussions around the displayed information as participants had access to content of the design of which they can respond to during the meeting session. For example, in a meeting session to review rendering of a brick wall, the participants had opportunity to react to or suggest modifications to the design information displayed on a large screen (see **Figure 4.1 and excerpt 1 [215:51.0-218:53.20]).**

Figure 4.1. *Participants collectively viewing information on a large wall display medium, while a member gestures to react to aspect of the information content during a meeting session.*

Episode 1 (E1), 21st of January 2018

Excerpt 1 [215:51.0-218:53.20]

215 B: *((Viewing and pointing to the VR model)).* I don't know why the ends of the brick are all dark.

216 A: *((Viewing and pointing to the VR model)).* Oh, that is nice at the ends.

217 D: *((Viewing the VR model)).* Yes, that is nice really.

218 C: *((Viewing and pointing to the VR model)).* In that way we could do that because I think it is dog-toothed excerpt that the rib is one brick wide.

For instance, in Figure 4.1 and Excerpt 1, the section of the brick wall in consideration is displayed on a large screen, whereby participants can simultaneously view the information and respond to the content. While viewing the brick wall on screen, Participant 'B' points to the ends of the brick wall to direct attention of the team members and comment, “I don’t know why the ends of the brick are all dark” (see Line 215, Excerpt 1). The comment of Participant ‘A’ drew the team’s attention to the edges of the brick wall presented on the wall display medium. While comment about colour of the brick ends attracted the team’s attention, they maintained their focus on displayed information. In contributing to the ensuing conversation about the rendering of the brick wall, Participants ‘A’ and ‘D’, appeared to have to be satisfied with the rendered colour of the brick wall by remarking, “…that is nice”. By responding to the colour of the brick wall in the affirmative, the participants appeared to have gained access to the content of brick wall of which they could react to its details in the ensuing discussion. Consequently, Participant ‘C’, joined in the conversation to endorse the appropriateness of the brick wall colour by elaborating, “In that way we could do that because I think it is dog-toothed excerpt that the rib is one brick wide”. The access and availability of the brick wall colour facilitated by the large wall screen, seemed to have informed the team’s conversations and sustained their exchanges. However, exchanges were limited to the activity area where team members could access and reference content of the brick wall in their submissions since the static nature of the wall display could not allow the team members to take turns in the manipulation of the information content to enhance their experience and inform their conversations.

In the case of interactivity characteristic of the display medium, the study revealed that the touch-sensitive interface of the SmartScreen medium incited varying ways with which the design team engaged with content of the 3D CAD rendering representation. There were a lot of dynamics in the verbal and non-verbal exchanges, mainly content manipulation, gesturing, evaluation and prediction of outcome of existing/alternative design decisions around the touch-sensitive interface characteristics of the medium. For instance (see Figure 4.2), in a design meeting to review the geometry and visual characteristics of walkway design the design team had mobilised a touch-sensitive (the capability to interact with design content via touch input) interactive display to visualise a 3D CAD rendering representation of the design. It was observed that participants interchangeably took turns to gesture at design information on screen and engaged in a lot of manipulations of the 3D CAD rendering (i.e., zoom, rotate and pan) to comment, obtain experience of different aspect of the design and provide additional information to enrich the evolving design.

For example, a participant (see Figure 4.2a), in an attempt to provide an alternative suggestion to the size and form of a railing component, moves from the activity area to the front of the touch-sensitive interface. He then zooms and rotates the railing panel and suggests, "…you can angle it this way before you choose where you want the angle to be, contrary to allowing the direction of movement to inform the shape of the panel". By moving to the screen area of the interactive display medium, the participant appeared to have been provided with the opportunity to gain control over manipulation of content of the design to suit his experience and aid elaboration of his suggestion. While the participant performs gestures and manipulates the information representation to facilitate his inputs, the non-verbal actions attracts other members who moves to the screen area to observe the suggestion being demonstrated on screen. In this case, the participants clouding in front of the screen also join in to participate in the conversation (see Figure 4.1b).

Figure 4.2. *Participants collectively viewing information on a large wall display medium, while a member gestures to react to aspect of the information content during a meeting session.*

Consequently, another participant take a turn in the ensuing exchange, points to the rail panel, zooms in and provides an explanation, " I think the reason we made that decision, I guess was to ensure that if the outside curve is angled then it is glazed on the outside of the curve, so you see through when you walk towards it". Hence, while the geometry and photorealistic features of the 3D CAD rendering representation of the walkway stimulated the conversation whereby attempted to respond to, the touch-sensitive feature afforded by the interactive SmartScreen medium contributed to sustain the interaction and encourage individual participation in the ongoing conversation. In this example, the interactivity feature of the display medium helped to provide different dynamics with which the design team engaged with design information and sustained the ensuing conversation since exchanges occurred both at the activity area and the screen area of which participants could easily gain control of manipulation and take part in the conversation.

Furthermore, the analysis reveals that the interactivity, display size and availability (ownership) characteristics of participants' mobile devices (tablets and smartphones) contribute to shape the dynamic exchanges in the team during the meeting session. For instance, in a meeting to review section of brick wall construction in a multi-housing design project, the design team relied on the use of their mobile devices to display sections of the 3D CAD rendering of the design. A team member while providing an alternative suggestion of the brick wall composition, shows a 3D model of the section of the design under consideration via his smart phone and passed on for other members to view (see Figure 4.3).

Figure 4.3. *A participant views design information displayed on smartphone while other team members wait for their turns to experience content of the design information during a meeting session.*

In this regard, the team members manipulate (i.e., zoom and pan) content of the brick wall composition for better view and experience via the touch input of the interactive interface. While manipulate to interact and engage content of the design information in turns, the participant pauses to allow individual participants experience the required content of the design. In this instance, the interactivity feature of the smartphone appeared to have enabled the participants obtain control over manipulation of the design content to shape their experience and inform their deliberations. However, while the participants continue to engage with details of the brick wall at the individual level, the dynamics in the exchanges expected to unfold among the team members to realise the review is task breaks down under such circumstances. Hence, the introduction of the smartphone to support the information needs of the participant provides different dynamics in the team's workflows. At one-point, individual members are provided with the opportunity to control the manipulation and promotes different experiences of the design content among the team members, whiles in another breadth, the flow of interaction and dynamics in participants' involvement declines.

This section has highlighted the salient features of both the information representation and the display medium utilised to support the exchanges in the team during the meeting session. The analysis has indicated that interactivity, display size and availability features of the display medium shape the dynamics of the use of the information content and the exchanges ensuing in the team. The summary of the findings is presented in below. The next proceeding sections provides more elaboration on how these salient features were utilised to support the verbal and non-verbal tasks of the team and their effect on the dynamic exchanges unfolding in the team.

Summary of salient features of information representation and medium mobilised during the meeting session

- The design team generally mobilised different forms of representations (VR models, 3D CAD renderings and 2D CAD drawings) and a variety of display medium (multi-display projector screens, wall displays, mobile devices, SmartScreen displays) to mediate their verbal and non-verbal actions and tasks.
- The use of the touch-sensitive interface, the screen size as well as navigation and walkthrough features of the medium incited different dynamics in terms of how the members participated in the team's exchanges and engendering different tasks.
- The utilisation of touch-sensitive feature of the medium provided variety of ways by which the team engaged and experienced design information and stimulated dynamic exchanges among the team members.
- There were a lot of dynamics in the verbal and non-verbal exchanges, mainly manipulation of information, gesturing and evaluation tasks around the touch-sensitive interface feature of the SmartScreen display compared to the non-interactive large wall display.
- The walkthrough and navigable features of the VR model were greatly utilised by the team members to enable access to varying forms of interior and exterior details of the design content.
- The photorealistic feature of both the VR model and the 3D CAD renderings stimulated and sustained extensive dynamics of exchanges among the team members, however, differed with different features of the display medium in terms of interface and screen size.
- The salient features of both the information representation and the display medium stimulated and sustained different kinds of dynamics in the exchanges of the team, however, each tended to affect the other in terms of dynamics allowed in the exchanges of the team.

4.3.2 Purpose of use of media

The study observed distinction with the purpose of use of the display medium and the information representation in mediating the actions and tasks of the design team during the meeting session. From the analysis, the design team used the display medium and its associated applications mainly to visualise and interact with design information, modify existing information via annotation and mark-up, as well as document and communicate design decisions. Furthermore, the analysis revealed that the design team used the display medium to structure the flow of interactions in the design meeting (see Figure 4.1 and Excerpt 1 [493:115.10-498:117.30]).

Episode 5 (E5), 24th of May 2018

Excerpt 1 [493:115.10-498:117.30]

A 493: *((viewing and pointing to section of the brick wall in the VR model)).* I think we need to consider the position of the brick wall again, either we want it to align with the entrance door.

B 494: *((viewing and pointing to the brick wall)).* But if we move it to align with that entrance door entrance what will happen to this attached door *((pointing to the door attached to the brick wall)).* I think we need to shield that door a bit.

C 495: *((viewing and pointing to the 3D CAD view)).* As it is now, we can move the brick wall to this area *((Pointing to the specific area of the interior space))* to align with that entrance door and still provide enough protection to the entrance.

A 496: *((viewing and pointing to the 3D CAD view)).* Ok.

B 497: Can we then capture it?

A 498: *((Create a digital photo of the brick wall area, annotate and mark-up to depict the new wall position)).* Use the mark-up and annotation functionalities of the Enscape plug-in for Revit application to mark up the new position of the brick wall.

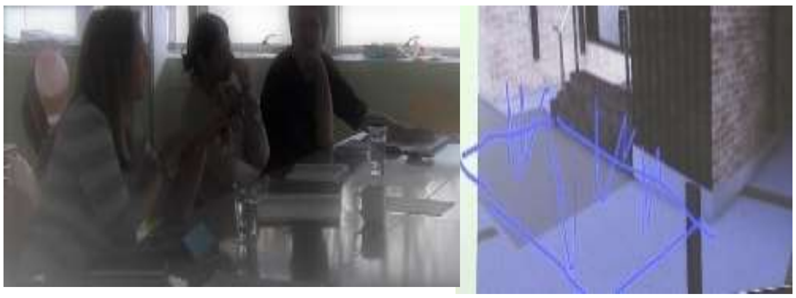


Figure 4.4. *Design team captures decisions on brick wall relocation as way of modifying the existing design content via annotation and mark-up tools during the review session.*

Excerpt 1 illustrates how the design team enacted purpose of use of the display medium to structure the emergent and situated of use of the salient features in the team's activities. In excerpt 1, the design team was confronted with the task of resolving issues with a brick wall position. Participant 'A', raised an issue about location of a brick wall by remarking, "…we need to consider the position of the brick wall again, either we want it to align with the entrance door" (Line 493, Excerpt 1). Consequently, Participant 'C' (Line 495, Excerpt 1) suggests "… we can move the brick wall to this area to align with that entrance door and still provide enough protection to the entrance". The suggestion to move the brick wall forward appears to have been endorsed by the team members as Participant 'A' (Line 496, Excerpt 1) responded "Ok" and Participant 'B' moved for its acceptance by remarking, "Can we capture it?" (Line 497, Excerpt 1).

The suggestion to capture the recommendations indicates how the design team have structured the use of the image capturing and documentation capabilities of the Enscape plug-in for Revit application. Participant ‘A’, who doubles as the technical operator then moves to mark-up, sketch and annotate the shape and new position of the brick using the mark-up and annotation features of the medium via mouse and keyboard inputs (Line 498, Excerpt 1). In this case, the decision to capture recommendations provided in the form of marks and annotations seemed to have structured how the mark-up and annotations features of the display were used in the ongoing activities of the team.

Excerpt 1 has highlighted how the design team decided to use specific facilities of the display medium through the emergent and situated practices of the team. For example, recording summary of recommendations in the form of mark-ups, sketches and annotations. The emergence of documenting the team’s decisions using the display medium also appears to inform how the mark-up and annotation features of the Enscape plug-in for Revit application was used in the ongoing and situated actions and activities of the team.

In another instance, for example viewing design information, the analysis shows that the design team enacted their use of the medium to visualise design information. From the observation the design team viewed the overall information first before descending to the specific details during the meeting session (Figure 4.5 and Excerpt 2 [261:78.0-264:79.40]).

Figure 4.5. *Design team viewing 3D virtual design information displayed in VR prior to verbal discussions.*

Episode 1 (E1), 21st of January 2018

Excerpt 2 [261:78.0-264:79.40]

X261: ((Viewing the VR model on the wall display medium))

B262: *((Viewing and pointing to the model)).* And is that picking something going through really?

A263: Yeah!

C264: *((Viewing and pointing to the landscape section of the model)).* I think that part is the start of the big crack. So, we can resolve it by stretching this side along.

In Excerpt 2, the design team was trying to identify and resolve design errors in the VR model during a design review session. Consistent with their practice, the team members viewed the VR model first to familiarise with its content. By viewing content of the VR model, Participant 'B' identifies an issue about the connection of a horizontal element, commenting "And is that picking something going through really?". The viewing of design elements in the VR model appears to have enabled the team member to engage with the fixing of the design element. Alarmed by the concern, Participant 'C' takes a turn in the conversation to clarify and prescribes a solution to the problem by suggesting, "I think that part is the start of the big crack. So, we can resolve it by stretching this side along". In this case, the opportunity to visualise the principal representation of the design before engaging with its content appeared to have structured how the team engages with the design during the meeting session.

These instances appear to suggest that decision as to how a medium with specific features is used to support collaborative task appears to be enacted by the people in team based on their social practices and opportunities afforded by features of the medium and the information representation.

Summary of purpose of utilising information representations and display medium in meetings observed

- There was a distinction with the purpose of use of display medium compared to information representation in facilitating the realisation of design tasks of during the meeting session.
- The design team enacted use of the display medium mainly to visualise, interact and modify design content as well as document design decisions.
- The information representation was purposely utilised to inform and stimulate actions towards accomplishing a design task during the meeting session.
- Both the display medium and the information representation fluidly contributed to shape the flow of interactions during the meeting session.
  The data revealed that team members structured their use of the technology based on both their digital practices in accomplishing a collaborative task and the features afforded by the media.

4.4 Communication instances observed

Interaction in design teams within digital spaces is considered a complex process, partly accomplished through the verbal communications of the team members as they engage design information. This section is concerned with the moment-to-moment communicative acts through which the team members understand and develop the evolving design during the meeting session. Specifically, it focuses on acts such as exchanging, describing, explaining, and evaluating observed in design meetings. The analyses are done in relation to media and information use as well as interplay with other actions.

4.4.1 Exchanging design information

This sub-section examines and explicates in detail how the team members exchanged design information to communicate the design during design meetings in relation to circumstances of their emergence, accomplishment and interplay with related activities. The analysis considers exchanging as sharing or showing displayed information on mobile devices (tablets, Smartphone) or other media such as sketches on paper across to participants.

The observation reveals that design team members occasionally exchanged design information to support their discussions during the meeting session. Participants at some points in the team's workflow showed design information in various representations via different displayed medium across to other members to familiarise with the design and inform their deliberations. However, sharing of information among the team members tended to vary in terms of nature of information, emergence, accomplishment and interplay with other activities across different media during the meeting session. Table 4.2 summarises the variations in information exchanges observed during the meeting session in relation to emergence, accomplishment and engendered tasks.

Table 4.2 Variations in exchanging of design information across different media during design meetings

Nature of information shared	Emergence	Method of accomplishment	Media (Features)	Engendered task
3D CAD renderings	To support a proposed suggestion	individual	Smart phone (portable, touch screen interface)	Explain, Navigate, View, Gesture
Digital 2D site photos	To provide update on state of design	individual	Smart phone (portable, touch screen interface)	Describe, Explain, Navigate, View, Gesture
Digital images of design elements	To resolve a misunderstanding on design decisions	individual	Tablet (portable, touch screen)	Describe, Explain, Evaluate, navigate, view, gesture,
Sketches	To interrogate proposed solutions	Sub-group	Paper (portable)	Sketch, view, gesture describe, explain, and evaluate

Source: Author's field data, 2018.

Table 4.2 indicates dynamics in information exchanges observed in the meeting session in relation to emergence and accomplishment as well as media and engendered task. The team members shared different types of information, including 3D CAD renderings, 2D digital site photos, digital images of design elements and sketches in the course of the meeting (Table 4.2). Mainly, the design team shared design information to support varying range of tasks, including update on design progress, clarify proposed suggestions, comment on alterative decisions and resolve misunderstanding in ensuing conversations. However, these activities were more revealing in terms of encouraging dynamic exchanges in the design with the shared sketches compared to the mobile devices (see Figures 4.6-4.7).

For instance, in a design meeting to evaluate a design proposal on incorporation of a shaft to support a roof member, a participant prior to taking a turn to participate in the discussion, picked his smartphone, browsed to open samples of the design consideration and showed to other team members (see Figure 4.6).

Figure 4.6. *A team member showing sample of design incorporating shaft on the roof construction to a fellow participant in a meeting session via a smartphone.*

By showing the information to the team members via the smartphone, participants had opportunity to experience content of the design information and react to it in the form of questions or contributions. For example, a team member upon interacting with the sample design of the roof construction remarked "…in that case how will we connect the shaft to secure the load of that roof segment, … if you look at how it has been positioned in the picture?" Consequently, while participants deliberated on the shared information, the issue of constructability stimulated further actions to evaluate and clarify concerns raised by the team members.

In another instance (see Figure 4.7), the design team members were evaluating the appropriateness of a brick wall connection. A participant sketched an alternative arrangement of the junction brick wall on a paper using a pen and passed it on while offering explanation to clarify a suggestion made.

Figure 4.7. *A participant in the design team shared a sketched object via paper and pen medium to colleagues to clarify a proposed wall connection alternative during a meeting session.*

By sharing the sketched object via paper medium as shown in Figure 4.7, other team members evaluated its viability, raising further questions. In reverse the participant offered further clarification via gesturing to illustrate how the connection will be formed (Figure 4.7). Although, the team members shared new information via both digital and paper medium to address design issues identified, these actions engendered undertaking of related actions to situate information sharing within the complex array of verbal and non-verbal behaviours brought together to realise a design task.

4.4.1.2 How the design team exchanged design information

The analysis revealed that the design team exchanged design information in two different ways, including sub-groups (i.e., a small number of people informally around a new information) and individuals (turn-by-turns). The mode of exchanging design information varied across different media and tended to shape engendered actions among the team members (Table 4.3). Interestingly, information representations in digital format (3D CAD renderings, 2D digital site photos and digital images of elements) via mobile devices (tablets and smartphones) were shared individually in turns during the meeting session. For example, in a meeting to update team members on progress of work in segment of a design project, the lead architect provided digital photos of wall construction captured on site displayed on her smart phone for members to view in turns while attempting to brief them on current state of work and decision on positioning of specific walls underneath the roof, remarking:

> "…this is a photo of the wall on line XFX on block C… so what we have done was taking a good line and given a line to the inner face of the XFX to the good line, so we know where XFX was sitting which was not doing further".

While the team members listened to the remarks of the lead architect, conversations to react on her submissions were temporary halted to enable participants view the shared photo in turns and engaged with its content via the touch sensitive screen of the smartphone (see Figure 4.8).

Figure 4.8. *A participant in the design team takes his turn to view a shared digital photo, and control manipulation of aspects of the design content during a meeting session.*

By providing participants opportunity to view the shared photos in turn via the interactive interface feature of the mobile device, members in the design team individually obtained control to manipulate the design information for enhanced understanding of its content. Although, looking at the digital photo on the smartphone in turns stopped the team's conversations about the new for a while, the individual members obtained new experience about content of the information, thereby aiding them to take part in later conversations.

In contrast to sharing design information in digital form, exchanging of sketched information in 2D paper format was accomplished in sub-groups, whereby a group of participants gathered around the sketched object to collectively interrogate it. For example, in a meeting to evaluate design decisions, a participant shared a sketch of railing object with a section of the team members to provide further explanation of a proposed changes to the railing component of the walkway design (see Figure 4.9).

Figure 4.9. *A section of participants gathered around a shared sketched object of a proposed railing member during a meeting session to familiarise and respond to its content.*

While elaborating on the sketched component, other members had opportunity to participate in the exchanges by raising concerns and providing inputs to transform the design. In this case, the discussion about the railing segment of the walkway were continued with the introduction of the sketched object, offering the participants a new experience of the railing object as well as encouraging their involvement in the conversation.

Summary of exchanging of design information during design meetings observed

- Participants in the design share additional information via digital and paper media individually and in small groups to help accomplish different tasks.
- The mode of exchanging design information varied across different media and tended to shape engendered actions among the team members.
- Sharing of information among the team members tended to vary in terms of nature of information, emergence, accomplishment and interplay with other tasks in different media during the meeting session.
- The size and interactivity of display medium shape the mode of information sharing, participants' experience with the shared information and dynamics of the exchanges that ensue in the team.
- Sharing of digital information via mobile devices was done individually while sketched information in paper format was accomplished in small groups during the meeting session.

4.4.2 Describing design information

The analysis reveals that the design team carried out descriptive task mainly to introduce a new topic or new information prior to evaluating its content. For example, in one of the design meetings to review design decisions on a walkway design project, the lead architect, who doubled as the meeting facilitator, extensively conducted the participants through aspects of the design while referencing the elements in the design, saying " …so this is the geometry of the method provided… the overall height is 1.25m and the width is 1.8m, and concentrated volume is 121" (see Figure 4.10).

Figure 4.10. *The lead architect (meeting facilitator) describes height of the railing portion of walkway design with the hand vertically spread apart while the team members observes during a meeting session.*

By preceding interrogations of the design choice with enough descriptions, participants in the design team had opportunity to seek for clarification and provide the relevant inputs required to modify the existing design. For example, upon listening to the description provided, a participant in the design team taking a turn in the conversation, asked "Why that height since the walkway is going to be used by kids also?". In this case, the description of design content prior to reviewing its details served to connect the team members to the various issues presented by the design.

4.4.2.1 How the design team accomplished descriptive task

The design team accomplished descriptive task through extensive reference to information representation, and manipulation of design elements via mouse and keyboard inputs and touch inputs. For example**,** in one of the meeting sessions supported by the 3D CAD rendering and the touch-sensitive SmartScreen interface, the lead architect, who doubles as the facilitator of the meeting performed different non-verbal interactions with both the 3D model representation of an aerial walkway design viewing, gestured at and navigated different aspects of the design to aid description of varying relevant content needed to inform the evaluation of design decisions. After obtaining the relevant views of the design through series of navigation and manipulation tasks (zooming, panning, rotating) via both the computer mouse and touch inputs, the participant makes a lot of references to the information content via verbal actions and series of gestural actions (pointing, spatial move and parallel indication gestures) onscreen to describe various aspect of the walkway design to the team members (see Figure 4.11).

Figure 4.11. *The lead architect describes various sections of the walkway design to team members while manipulating the design content via the touch-sensitive interface during a meeting session.*

However, descriptive tasks that occurred in the VR model and the large non-interactive wall interface of the wall display, participants took turns to describe aspects of the design mainly from their activity area contrary to the touch-sensitive SmartScreen display support medium (see Figure 4.12).

Figure 4.12 *A participant in a VR model supported design meeting session describing nature of the landscape provided while viewing and gesturing from the activity area.*

In Figure 4.12, a participant attempting to clarify an issue with the incorporation of the landscape in that section of the design, describes how provision of landscape in that area serves to beautify the place since a bicycle rack is provided in front of the it, saying “ Looking at the placement of the bicycle rack, the size of landscape is appropriate to protect that portion of the wall”. In this example, the walkthrough functionality and photorealistic model of the landscape material and the bicycle provided better experience of the relevant details of the landscape required to simplify the description. Hence, referencing it from a distance was enough to aid the needed understanding required to inform the teams’ deliberations.

While participants described design elements in the VR model supported meeting mainly from the activity area, the design team performed related tasks such as viewing, navigating and gesturing actions to complete the descriptive task. For example, a participant in the VR model supported meeting, while describing a brick arrangement of a wall component had to navigate, transition to a 2D CAD elevation view of the wall in consideration to thoroughly describe nature of the brick arrangement to the team members (see excerpt 1 [467:78.0-468:79.15]).

Episode 5 (E5), 24th of May 2018

Excerpt 1 [467: 78.0-468:79.15]

467 A: *((Viewing and pointing to the VR model)).* This part of the brick wall is dark at the end. *((Navigate to transition to the 2D CAD elevation view of the brick wall)*. When you look at the brick in elevation too, it is clear. That portion is dark and slides in *((Pointing to the 2D CAD elevation view)).*

468 C: *((Viewing and pointing to the 2D CAD elevation view)).* Yeah, I see. But initially the colour arrangement was not clear.

Excerpt 1 exemplifies an instance in which the design team needed to resolve issues on a brick colour arrangement of a wall panel in the VR model. Participant 'A', who doubles as the navigator of the VR model needed to provide a lot of descriptions on the brick wall colour arrangement to enable the team members take decision on the brick colour. In line 467 (Excerpt 1), Participant 'A', describes the brick colour of the wall panel while pointing to specific portion of the wall element by remarking, "This part of the brick wall is dark at the end". While describing the photorealistic model of the brick colour, Participant 'A', navigates and switches to display a 2D CAD representation of the brick wall to provide further elaboration, "When you look at the brick in elevation too, it is clear" (Line 467, Excerpt 1). The elevation provided further details about the colour shades and how they were tiled to aid understanding of colour choice needed. Consequently, Participant 'C', proceeds with a remark, "Yeah, I see. But initially the colour arrangement was not clear". The statement of Participant 'C' (Line 468, Excerpt 1) indicates that augmenting the description of the brick colour in the VR model with the 2D CAD elevation view contributed to simplify the elaboration and helped to provide richer details needed to inform the team's decision on the relevance of the colour choice as used in the design. The transitioning to different representations and actions to accomplish the descriptive task suggests the dynamic nature of the descriptive, and how it is intertwined with other non-verbal actions within the context of its emergence.

This section has touched on how the design team accomplished descriptive task during the meeting session. The analysis has learnt that descriptive is realised through extensive referencing of varying features of the information representation including photorealistic nature, geometric characteristics and manipulation of information content using the touch sensitive interface as well as mouse and keyboard inputs. Besides, participants fluidly intermixed verbal descriptions with viewing, gesturing and navigation actions to describe content of design information. It is also highlighted that descriptive activities tend to proceed from both the activity area and touch-sensitive interface screen, however, onscreen activities stimulated a lot of dynamic exchanges among the team members.

Summary of nature of descriptive task in design meetings observed

- The design team accomplished descriptive task through extensive reference to information representation, and manipulation of design elements via mouse and keyboard inputs and touch inputs.
- Descriptive tasks in the VR model, large wall screen supported meeting mainly occurred at activity area contrary to the touch-sensitive SmartScreen display support medium where a lot of descriptive tasks took place onscreen.
- Descriptive tasks around the touch-sensitive interface feature of the display medium were more dynamic and engaging in terms of participants' involvement and incorporation of related tasks compared to the VR model.
- The design team fluidly intermixed description of design elements with related tasks such as viewing and gesturing as well as navigating and onscreen manipulative actions to complete the descriptive task.

4.4.3 Explaining design information

From the analysis, the quest to explain design information emerged in different circumstances, including clarifying design issues, responding to design queries, as well as elaborating proposed suggestions during the meeting session. For example, in a meeting to review design decisions on a proposed aerial walkway design, the design team were evaluating the geometry of the steel structure, specifically, the height (see excerpt 1 [116:35.30-118:36.50]).

Episode 4 (E4), 24th of March 2018

Excerpt 1 [116: 35.30-118:36.50]

116 A: *((Pointing to the 3D CAD rendering of the walkway design)).* The geometry of the GC method has 25m radius, 60m radius CL and the rail crossing which is straight. The proposed height for the steel structure is 1.25m.

117 B: ((Viewing and pointing to the 3D CAD rendering of the walkway design)). My concern is with the height of the steel structure as it is now. Just in case the kids run through the rails since parents will be lifting up their kids when using the walkway.

118 D: Yeah, it is true. The lifting up is an issue with this type of walkway. But I think the good news is that it does not happen in a chaotic case some high within the range. *((Moving to the front of touch-sensitive screen of the SmartScreen and gesturing)),* the rationale for that consideration is that steel seems to happen I think that height with wood on top to the rail, definitely that is a problem if parents are lifting their kids up. So, it is just feeling that this height is the safer that is why we went for it from our experience on this type of design *((gesturing to depict the height)).*

119 B: Ok. The overall concern is safety, because people with different height could have completely different experience in that case.

The height of the steel structure became an issue which needed to be resolved by the team members (Excerpt 1). For instance, Participant 'B' (Line 117, Excerpt 1) appeared to have an issue with the proposed height, “My concern is with the height of the steel structure as it is now. Just in case the kids run through the rails since parents will be lifting up their kids when using the walkway”. The concern mainly happened to bother on safety of kids likely to use the walkway, considering the possibility of being lifted by their parents. With this concern, the project team members needed to provide further elaboration on the decision and allay doubts in the participants. Consequently, Participant ‘D’, who happened to be a member of the project team, moves to the front of the touch screen, gestures at the geometry of the 3D CAD rendering representation of the steel structure and explains “…the rationale for that consideration is that steel seems to happen, I think that height with wood on top to the rail …. So, it is just feeling that this height is the safer that is why we went for it from our experience on this type of design”. The explanation provided by Participant ‘D’ seems to have clarified the initial concerns of the team with regards to the height of the steel structure.

However, while the explanation appeared to have enhanced members understanding of the proposed height, it also stimulated other discussions on safety issues, as remarked by Participant ‘B’, “The overall concern is safety, because people with different height could have completely different experience in that case” (Line 119, Excerpt 1). The mention of safety issue, in connection with use of the walkway changed the current discourse of explaining rationale of the design choice to evaluate the overall safety of the proposed walkway. The switch from explanative task to evaluation and the usage of gestures seems to show that explaining aspects of design information seems to be realised in connection with other types of actions, including evaluation.

4.4.3.1 How the design team accomplished explanative task during the meeting session

According to the data, the design team accomplished explanative task in connection with other related non-verbal actions, including gesturing, navigating, and mobilisation of personal mobile devices (tablets and smartphones). The participants in the design team extensively switched between different tasks while attempting to explain design issues to clarify misunderstandings and elaborate on design choices during the meeting session. For instance, in a meeting to review design decisions in the VR model representation, the team members were attempting to resolve a constructability issue in relation to an aluminium panel connection. While viewing the aluminium panel that connects to the brick wall, a participant explained how the aluminium panel could be fitted to the brick wall by gesturing with the two hands to support the clarification, saying "… what I mean is that, we can draw that angle connection down to the adjoining brick wall, because the edge of that brick wall is toothed" (see Figure 4.13a). This elaboration appeared to have enhanced understanding among the team members as another participant remarked, "Ok. In that case, the aluminium panel will be moved back a bit to separate it from the main wall. That sounds good". By interspersing gesturing with the verbal explanation as well as the existing information, the explanative task appears to have been simplified to aid understanding about the connection of the aluminium panel and the brick wall.

Figure 4.13. *The design team utilising different non-verbal actions and mobilisation of mobile devices to support their explanative tasks.* ***a*** *A participant in a design meeting gesturing and viewing design information on display to explain a design decision.* ***b*** *A participant viewing a photo of an insulation board-wall construction via smartphone during a meeting session.*

In another instance, the design team were evaluating the geometry of an insulation board in a proposed wall construction. To provide elaboration on a proposed suggestion, a participant picked his smartphone, browsed through to display an image showing example of the nature of insulation board proposed. He passed it on to other team members to view and gain experience of it (see Figure 4.13b). Afterwards, the participant went ahead to explain, "…if we lower the thinner insulation board as suggested, we will only need 150mm between the top, the finish surface and the threshold as you can see in the picture shown". In this case, the participant needed to provide new experience of the details of the insulation board to the team members for clarity and encourage their involvement. The introduction of the new information via the smartphone to demonstrate nature of the insulation board appears to have aided the explanative task as more referrals were made to the example. This suggests that incorporation of additional information via mobile devices and use of gestures as well as viewing actions appeared to have supported the explanation of design issues and helped to sustain the dynamics of the exchanges during the meeting session.

Furthermore, the observations show that the design team extensively utilised both existing and new information, including VR models, 3D CAD renderings and 2D CAD detail drawings to support their accomplishment of explanative tasks. For example, in a meeting to identify potential issues and provide recommendations in a VR model supported design meeting, the team members identified an issue with a construction model required to support a railing member (see excerpt 1 [344:67.30-346:71.20]).

Episode 5 (E5), 24th of May 2018

Excerpt 1 [344: 35.30-346:36.50]

344 A: *((Viewing, virtually walking through the model and pointing to a horizontal structural model and a railing)).* This structure I guess you know what it is. That is a construction model required to receive the railing. And that is where the brickwork stops. I don't know what we are going to do with that end. Do we start from there, or what?

345 D: Just like the landscape, it just has to be raised up there a bit higher than the slope to receive the railing *((Pointing to the construction model and the railing)).* The reason is to tie up with it *((pulls his notebook, produced a sketch and shows it to the team members))*. So, if you look at this sketch *((pointing to the sketched diagram))*, here is the existing level leading to the landscape area, so the end here can be prepared to receive the railing.

346 B: Yeah, that sounds good.

Excerpt 1 demonstrates an instance in which the team members attempted to resolve an issue with a constructional model during a meeting session. The resolution demanded that participants receive enough clarity about rationale informing the design choice. Participant 'A' (Line 344, Excerpt 1), who doubles as the navigator, identifies the issue while virtually walking through the model and remarked, "…That is a construction model required to receive the railing… And that is where the brickwork stops. I don't know what we are going to do with that end…". Participant 'D' attempts to provide a suggestion to address the issue. He referenced landscape content via pointing and suggests, "Just like the landscape, it just has to be raised up there a bit higher than the slope to receive the railing" (Line 345, Excerpt 1). In this case, the geometry and visual characteristics of the landscape are utilised as a bases for the proposal. While Participant 'D' provides suggestion about how to address the railing problem, he further provides explanation about the reason of his claim, with the support of a sketched diagram, saying " The reason is to tie up with it " …if you look at this sketch, here is the existing level leading to the landscape area, so the end here can be prepared to receive the railing" (Line 345, Excerpt 1). The sketched object seemed to have shown enough details about how the base of the railing connects to the end of the construction model since the photorealistic nature of the construction model and the railing did not show details of their fixing. The follow-up explanation provided by Participant 'D' through the support of sketched diagram appeared to have resolved the construction issue as remarked by Participant 'B', "Yeah, that sounds good" (Line 346, Excerpt 1). This excerpt highlights that participants rely on various features of information representation as bases to inform their explanations in justifying their propositions during the meeting session.

4.4.3.2 Explanative task in different representations and display medium

The analysis reveals that there were more dynamics in the exchanges to accomplish explanative task in the 3D CAD rendering, touch-sensitive support meetings compared to the VR model supported meeting in terms of involvement of participants and incorporation of related actions. The touch-sensitive interface of the SmartScreen appeared to have incited more onscreen manipulation activities via touch input and gesturing. The observations revealed that onscreen manipulations and gesturing of design information helped the participants to gain new experience about content of the design. For example, in a meeting session to evaluate the merit of incorporation of holes on sides of the steel structure forming the walkway, participants fluidly combined gestures, zooming and rotating actions to manipulate aspect of the design while providing explanations to support their suggestions. An instance of this is seen in Figure 4.14.

Figure 4.14. *A section of participants gathered in front of a touch-sensitive interface of the SmartScreen medium, while a participant gestures and manipulates section of the steel structure to explain relevance of holes on sides of the walkway structure.*

In Figure 4.14, a section of the participants was reacting to a proposition by a team member and had gathered around the touch-sensitive interface for more elaboration on sizing and positioning of holes on the sides of the steel structure. While responding to concerns of the team members, the participant points, zooms aspect of the design and explains, “the idea is that incorporating these holes is meant to link users to the railway section of the walkway to enhance their views". The explanation stimulates other issues in connection with client requirements. In this case, one of the participants gestures at the steel section of the design and asks, "Is the idea approved by the client?". The participant moves in to provide further response, explaining, "It is one of the ideas we have push to the client, but we are yet to conclude". The onscreen manipulations via zooming and rotating to experience and address specific design concerns, as well as gesturing appears to have incited more exchanges among the team members to clarify and gain new insight about the design.

Summary of nature of explanative task in design meetings observed

- The quest to explain design information emerged in different circumstances, including clarifying design issues, responding to design queries, as well as elaborating proposed suggestions.
- The design team accomplished explanative task in connection with other non-verbal actions, including gesturing, navigating, and mobilisation of personal mobile devices (tablets and smartphones).
- The design team extensively utilised both existing and new information in the form of VR models, 3D CAD renderings and 2D CAD detail drawings to support accomplishment of their explanative tasks.
- There were more dynamics in the exchanges to accomplish explanative task in the touch-sensitive interface support meetings compared to the VR model supported meeting in terms of participants' involvement and engendering of related actions.

4.4.4 Evaluating design information

The analysis reveals that evaluation is a dynamic communicative task extensively carried out to realise different design goals, including authenticating merit of design choices, checking compliance to requirements, comparing alternatives and resolving concerns. For example, in one of the meeting sessions to evaluate relevance of roof object and its connectedness with a wall panel, the design team switched between judging appropriateness of design choice, resolving a concern and checking statutory compliance to complete the evaluation task (see excerpt 1 [135:19.30-138:21.10]).

Episode 1 (E1), 21st of January 2018

Excerpt 1 [135: 19.30-138:21.10]

135 B: *((viewing and pointing to the model)).* So, what can be done with inclusion of the roof safety item on the roof?

136 C: *((Viewing and pointing to the model)).* Yeah you could put some hooks probably not on the ribs but the other end, and then you just clip onto that.

137 A: *((Walking/flying through, viewing and pointing to the model)).* Let's get onto that because I may just raise it. So, we got start to talk about those junctions there and whether or not they are. So that wall which reality is that door which is returned round the corner is far a statutory concern.

138 D: Yeah, that is good observation.

Excerpt 1 illustrates an instance in which the team members attempted to satisfy themselves with the inclusion and positioning of a safety item on a roof component in one of the meeting sessions supported by a VR model and a large wall display. Participant ‘B’, in line 135 (Excerpt 1), raises a concern about the incorporation of the roof safety item, “…what can be done with inclusion of the roof safety item on the roof?” The query about relevance of the safety item in connection with function of the roof, requires that the team engage in discussions to justify the merit of that decision. Consequently, by viewing and pointing to reference the safety object, Participant ‘C’, suggests changes to its current position and construction, remarking “...you could put some hooks probably not on the ribs but the other end, and then you just clip onto that” (Line 136). By offering a new proposal to the position and fixing of the roof safety item, the goal of the evaluation task changes from raising a concern to deliberating on an alternative solution. While the team considers the new proposal to ensure appropriateness of the location of the safety item, Participant ‘A’, who doubles as the navigator, virtually walks and fly through the model to obtain a broader view of the roof safety item via the mouse and keyboard controls. Participant ‘A’, further requests for more deliberations beyond the initial suggestion of changing its location, saying “Let’s get onto that because I may just raise it” and “…the corner is far is a statutory concern” (Line, 137, Excerpt 1). The concern of Participant ‘A’, which initially centred on merit of the roof safety in relation to the adjourning wall and door element, switches focus of the evaluation task from function of the roof object to a safety compliance issue. By fluidly changing the focus of evaluation task to realise different goals considered relevant by the team to refine the design decision, the evaluation task becomes dynamic in its use to develop the evolving design.

4.4.4.2 How evaluation task was accomplished

With regards to accomplishment of evaluation task, the observations indicate that its accomplishment is intricately connected with array of tasks including explanation, sketching, gesturing, navigation and manipulation of design content. The observation reveals that the design team fluidly switched between these range of tasks to accomplish an evaluative task. For example, in a meeting session to interrogate appropriateness of V-column to provide a vertical support to the rest stop section of a walkway design, participants zoomed in to manipulate specific content of the design element, gestured at relevant portion of the element via touch-sensitive interface of the SmartScreen and switched to sketching to aid their evaluation task (Figure 4.15a, b, c).

Figure 4.15. *The design team embark on evaluation task.* ***a*** *A section of participants gathered in front of the SmartScreen touch-sensitive interface while a member manipulates aspect of the design via touch input to elaborate further on an earlier concern a meeting session.* ***b*** *A participant queries proposed arrangement to transition between the walk area and the rest stop section of the design on-screen while other members gather around.* ***c*** *A participant in the design team switched back from the SmartScreen interface to sketch an alternative V-column connection to respond to a question and justify its appropriateness.*

4.4.4.3 Evaluation task in different representation and display medium

The observations indicate that accomplishing evaluation task vary with different goals and characteristics of representations and interactive interface. For example, in one of the meeting sessions to interrogate design decisions on an aerial walkway design, the participants extensively carried out a lot of evaluative tasks in front of the touch-sensitive SmartScreen interface compared to the activity area (see Figures 4.16 a, b). For instance, in Figure 4.16a, a team member while commenting on surface exposure of a proposed railing material, moves to the front of the touch screen, gestures with the hands spread apart to demonstrate how light reflection could be adjusted, saying " …everything is about looking out or accepting to look up or having effective light channels in the way, in that case the idea of using reflective materials had to be slightly adjusted as it now." Consequently, another team member joins in to provide further elaboration drawing on the previous suggestion by remarking, " I think if the surface exposure is modified, it will improve ease with which the kids will use the walkway in the night while transitioning between the discovery site on top of the trees and the water-tight site." (Figure 4.16b).

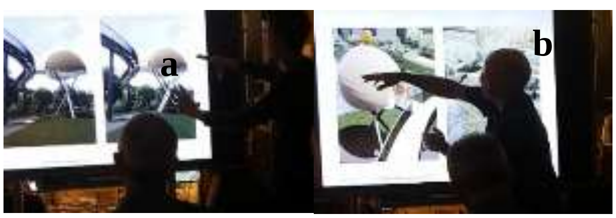


Figure 4.16. *The design evaluating a design decision.* ***a*** *A participant relying on photorealism nature of the design, gestures with two hands spread to support a suggestion while commenting on surface exposure of a railing material in front of an interactive screen interface;* ***b*** *A team member gesturing with a spatial move gesture on the displayed information on screen while providing further justification on the need for adjusting the reflectivity of the material during a meeting session.*

In these instances (Figure 4.16a, b), the participants extensively relied on the visual characteristics of the 3D CAD rendering, the manipulative control of design content afforded by the interactive interface and varying forms of gestures to support their submissions. The photo realistic nature of the 3D CAD rendering of the walkway, coupled with the touch sensitive interface supported in stimulating a lot of manipulations and on-screen activities to obtain better view of the design. By incorporating the rendering and geometric features of the information representation, coupled with the onscreen gesturing actions, evaluation task is accomplished through extensive dynamics in the participants' behaviour. The onscreen activities to evaluate elements of the design which was afforded by the touch-sensitive interface of the SmartScreen stimulated and sustained a lot of dynamics in the verbal conversations and gesturing actions to accomplish the evaluative task.

Summary of the nature of evaluative task in design meetings observed

- Evaluation is a dynamic communicative task extensively carried out by the design team to realise different design goals, including authenticating merit of design choices, checking compliance to requirements, comparing alternatives and resolving concerns.
- The evaluation task is accomplished through intricately interconnected array of tasks including explanation, sketching, gesturing, navigating and manipulation of design content.
- Accomplishment of evaluation task vary with different goals and characteristics of representations and interactive interface.
- The evaluation task was extensively supported using touch-sensitive interface of the SmartScreen, walkthrough feature of the VR model and photorealistic nature of both VR model and the 3D CAD renderings.
- Evaluation task was more dynamic with the use of touch-sensitive interface feature of the SmartScreen display medium.

4.5 Interactions with media

The study characterised interaction as physical engagement with a media, as the team employs to facilitate their moment-to-moment acts in their workflows. The analysis basically focuses on both interactions with a particular digital medium and the representation of design information, thus seeking to differentiate the medium with which participants encounter design information and the nature of representation the digital information is presented. Contrary to prior studies (Liston, 2009; Liu, 2016; Tory et al., 2008) which often lumps the two, this study considers their differentiation critical to enriching understanding of meeting dynamics and informing mobilisation of digital resources and planning of effective design review meetings in digitally-enabled spaces. From the analysis, the study observed wide range of interactions with the media in varying degrees and detail across different media environments. However, the dominant act types emanating from the video data comprised viewing, annotating, navigating and gesturing. The remaining sub-sections explicate in detail the key aspects of interaction with media and with design representations. These explanations are done in relation to the circumstances of their emergence and accomplishment.

4.5.1 Viewing

From the observation, the most dominant action with media during the design review sessions among the team was to view current design information presented on display screens. However, the observation presents a lot of dynamics in viewing of design information within the meeting sessions witnessed (see Table 4.3). These viewing dynamics appear to shape flow of interaction in the team along several dimensions which tend to influence understanding of the role of viewing in facilitating collaboration among the team

Table 4.3. Types of viewing in relation to other interactions and media

Viewing type	Related actions	Purpose	Media	Consequence

Group	Navigate (orbit, 3D walkthrough, 3D flythrough), Hand gesturing (pointing), query, describe, explain, evaluate	Support group goals and activities	VR model, 3D CAD renderings, large display screen	Converge overall team attention
Sub-group	Navigate (Orbit, zoom, pan), hand gesturing (pointing), query, describe, explain, evaluate	Obtain additional information	New information, Mobile devices hand-drawn sketches; restricted display	Disrupt interaction flow
Individual	Navigate (Zoom, pan)	Obtain additional information	Mobile device, new information	Disrupt interaction flow

Source: Author’s field data, 2018

The analysis revealed three types of viewing among the design team, which seemed to vary across different display mediums. Design team members viewed information either individually, in sub-groups or whole group (Table 4.3). While the design team simultaneously viewed information on unrestricted display spaces such as the multi projector screen, and wall displays, information displayed on mobile devices such as tablets and Smart phones as well as 2D traditional paper media, permitted information viewing in turns, only by one or two persons at a time or at best in sub-groups. This phenomenon halted the flow of work in the team, allowing for individual participants to familiarize themselves with the displayed information. Group viewing was predominantly remote and preceded utilisation of the medium and the design information to accomplish goals of the team (Figure 4.17).

Figure 4.17. *Viewing of design information together in group.* ***a.*** *All the design team members together viewing information in a 3D CAD rendering displayed on screen in a collaborative discussion with accompanying gestures and conversations.* ***b.*** *Participants in a design meeting session together viewing design information in VR model representation on wall display prior to evaluating aspect of the design content.*

From the analysis, another significant dynamic in group viewing was occasional request for seeing different perspectives of the internal and external aspects of the design information before commencing discussions. Typically, these phenomena were predominantly witnessed in the VR model in the Enscape plug-in application for Revit architecture, where tools required for navigating varying views of objects in the model were readily available. Besides, the desire in team to obtain broader and comprehensive perspectives of the design information in VR model representation was accomplished mainly in connection with navigating acts such as walkthrough/fly-through, orbiting/rotating, and hand gesturing via pointing (see excerpt 1 [121:16.0-129:17.25]).

Episode 1 (E1), 21st of January 2018

Excerpt 1 [121: 16.0-129:17.25]

121 B: *((viewing and pointing to the VR model)).* Should I delete that ladder?

122 C: Yeah

123 A: *((Pointing to the model)).* Well then, where can we get over that?

124 D: Can we view the staircase from the other side of the room to obtain a better perspective?

125 X: *((orbiting, Walkthrough the model to side of staircase as suggested, and viewing)).*

126 C: I think this is going to be, you don't get there, and you get there via internal stair and the entrance door into that internal corridor.

127 B: *((pointing to the model)).* Yeah, because that ladder is always going down the other end. You just have to climb the upper ladder.

128 C: *((viewing and pointing to the ladder in the model)).* So, the ladder comes around and she comes up there from that end. You said it is 3.4 metres.

129 " A: *((view creation, 3D marking up, annotation and saving)).* Good! This is the stage I was worrying about, and that is alright.

Excerpt 1 exemplifies a different circumstance under which viewing of design information emerges and is accomplished during a meeting session. The excerpt also portrays the interlinkage between visualising, navigating and gesturing (pointing) as non-verbal interaction, and the conversations stimulated within the participants' ongoing engagement with media. Designer 'A' expresses concern about the suggestion of Designer 'B' to delete a ladder located in the interior space within the model with reference to accessibility issues. In resolving this conflicting view, Designer 'C' suggests changing viewing perspective of the staircase from the opposite end to obtain different and broader perspective in resolving the problem. The designer controlling navigation in the virtual walkthrough model orbits and walkthrough the model via keyboard and mouse control to the desired location in relation to the staircase. This sequence illustrates how the team changes viewing of design of design information in the group through their collective effort. This seems to suggest that viewing of information among the entire team is dynamic, and also tied to the needs of the team at a particular moment. Besides, the excerpt appears to hint that different types of non-verbal interactions are intermixed to accomplish a collaborative task. Hence, suggesting that interaction in the activity of design review is complex, and as such verbal and non-verbal actions appear to be fluidly interlinked to engender and sustain collaboration in interaction process. The participants switched between non-verbal and verbal acts while each of these actions generate conversations around the design information, and also stimulate a meaningful next turn in the turn-taking aspect of interaction.

Interestingly, while the team relied on large display screens such as multi-projector and wall display screens for group viewing, information representations were viewed in successions. Presentation of design information on large and multi-view screens occurred one at a time during the group viewing session.

Figure 4.18. *The team viewing design information in virtual walkthrough representation.* ***a.*** *A single design information displayed for viewing.*

Episode 1 (E1), 21st of January 2018

Excerpt 2 [001:01.1-002:02.11]

001 X: *((Viewing the VR model displayed on the wall screen))*

002 A: Our figure is the VR model of the project design for the industry. Also, we can crossover to the digital clip drawings opened in tabs if we need to…

Figure 2 and excerpt 2 exemplify arrangement of viewing design information in at the group level in a digitally mediated design meeting session. Designer A, who acted as technical operator of the VR model enabled design review meeting proceedings displays a single representation of current state of the model on wall screen and orient the team on viewing arrangements as the session unfolds. While the team views the current version of the model on display, Designer A indicate to the team that digital clips of different representations of the model are arranged as tabs and consulted when the need arises. This development illustrates how the team arranges viewing of design information as the meeting progresses. The team viewed information on display one at a time, mainly after exhaustive interrogation of the current information, or when additional insight was required before switching to view new information. The observation appears to suggest that the team attaches high premium to viewings which provide rich data about model elements to simultaneous viewing of information during discussions in order to remain focus on the relevant information.

Conversely, in the case of sub-group viewing, team members in the same proximity often converged around one of the participants, in most cases, the originator/owner of the information and the media to view the information. Interestingly, in this mode of viewing, participants picked up conversations in the form of queries and comments about the quality and availability of relevant information (Table 4.3). Consequently, manipulations in the form of zooming, rotating and panning of the design representation were mostly performed to aid better perspective and understanding of relevant information needed for meaningful discussions. As a typical example in the observation, a designer participating in a discussion towards resolving a design issue during a meeting session, showed a proposed solution sketched on paper to a section of the team members. The designer did this in the quest for new information as alternative to the existing proposal. Significantly, while the team members rally around the sketched object to view the information, the designer interspersed the viewing action with hand gestures via pointing to explanations and engage the members in further conversations (see Figure 4.19a).

In similar instance, a member offered to share additional information on specific element in a 3D BIM model he has searched for via his smart phone to participants sitting nearby. The member showed the displayed information on his smartphone as he took his turn to people in close proximity before contributing to the discussions around the model (Figure 19b). This phenomenon was observed to be occasional, especially in meetings mediated by the 3D CAD rendering and the wall VR model. While this development was seen as innovative on the part of the team members, the flow of the interaction appeared to be disrupted in the ensuing group viewing.

Figure 19. *Viewing of design information in sub-groups.* ***a*** *A group of designers viewing design information sketched on 2D paper in the course of the meeting and picked up spontaneous conversations around it.* ***b*** *Two design team members viewing design information displayed on smartphone screen.*

In the case of individual viewing, the snapshots in Figure 4.20 are provided to explicate the dynamics observed as team members viewed design information in turns.

Figure 4.20. *Team members viewing design information on mobile devices in turns.* ***a.*** *A design team member viewing design information displayed on Smartphone screen while others wait to take their turns during a design meeting session.* ***b.*** *A participant in the design team viewing and manipulating design information via tablet interactive screen to obtain different and better view of the information as she took her turn in the turn-taking viewing arrangement during a design review session.* ***c.*** *A participant in the design team accompanied viewing of design information generated on smartphone with navigating acts such as zooming and panning to identify and understand specific aspect of information during one of the turn-taking viewing sessions.*

The snapshots in Figure 4.20 depicts how individual viewing of design information emerged and accomplished in the design team during a meeting session. In Figure 4.20a, a designer views a new information displayed on smartphone during her turn while other members look in readiness to their take turns. Similarly, in Figure 4.20b, a participant in the navigate information displayed on tablet as the team pulses proceedings to allow space for the viewing exercise. Displayed information via the mobile devices mainly reached the next viewer after previous person has adequately interrogated the information. This interrogation often interspersed with navigation moves such as zooming, panning and rotating necessitated by the interactivity of the interface. However, in rare occasions, participants voluntarily requested access for viewing of the new information outside the normal turn-taking arrangement when needed to critically appraise and inform meaning contribution. This illustrates that the team appears to halt deliberations in the course of the meeting to provide opportunity for members to familiarise with new information displayed on restricted devices.

With regards to understanding opportunities offered for collaborations in the emergence and accomplishment of viewing actions, the analysis revealed evidence of collective working among participants in the design team. However, extent of engagement seems to vary across the viewing forms. While viewing of design information, irrespective of the form, generated some conversations and follow-up actions, conversations tend to be intense in the group viewing. This appear to emanate from the fact that team members had simultaneous encounter with the design information, hence converging their multiple expertise into the process of explanations and resolutions which often emerged around these acts.

In contrast to studies of team interactions in mediated spaces which seek to isolate and quantify discreet acts of interaction, and focus analytic orientation of non-verbal interaction with the technological artefact (Liston, 2009), this analysis, drawing on the principles of Interaction Analysis (IA), and the concept of technology-in-practice lens argues that action is emergent and situated within the context of practice. Hence, understanding ongoing and situated use of media in digitally enabled space, as well as design information the in a prevailing activity, need to account for both the purpose and occurrence of the action in the media interaction discourse. The observations revealed that, viewing of design information often occurred prior to undertaking of a goal-oriented task. An instance of this is exemplified in Excerpt 3 [001:00.02-008:01.35].

Episode 1 (E1), 21st of January 2018

Excerpt 3 [001: 00.02-009:05.35]

001 B: *((Viewing the VR model on a wall display))* I was thinking brick colours by corners because we have looked at it before. I don't know if we can do much with spacious or maybe colours generally are stuffs in models are anomalies that should be or not be, but other stuffs can be looked at.

002 A: I think that is good.

003 B: Landscape… I think you mentioned landscape.

004 A: Yeah. We need to also look at the interface between landscape and architecture, and whether there is any particular bit we need to look at in terms of what they have done at the moment. I know that they have got brick landscape walls which I have changed the colours to match up the colours of what we are doing.

As we get particular brick details the rest is just to carry that on or that sort of thing and just a few drenches at the moment we need to it off. I don't know to what extent you feel we should be looking at things like bigger things so we might resolve.

005 C: *((Viewing the VR model displayed on the wall screen))* I think we can see of the model. The moment I look at the 3D I could see some problems and stuffs like that.

006 A: Oh yeah… That is correct.

Excerpt 3 presents an instance of the design team viewing design information in 3D virtual walkthrough model representation displayed on a large wall screen before undertaking a task

[001]. Designer A displays the 3D virtual model on the wall screen to the design team whiles the team members view its content. While the team keenly look at the model, Designer A provides general orientation of the model and solicits views opinions from members on what to do and where to proceed from [Line 002]. As the team views the model to support their decisions, Designer B takes a turn and suggest landscape by colour, while Designer C also raises some design concerns upon looking the model. Consequently, the team commenced work by first reviewing landscape component of the model as suggested by member B. In excerpt 3, viewing action on design information appeared to serve as a resource for the team by stimulating conversations about possible tasks and activities to undertake as the meeting progresses. Besides, the participants obtained opportunity to perceive and understand the design thereby information their decisions on relevant task and activities to embark on, and also manage the interaction process. What this seems to suggest is that, the design team relied on viewing action to perceive and understand overview of the key elements of the 3D virtual model with the purpose of supporting their goal-oriented activities and task. The development appears to indicate that viewing of design information provided opportunity for participants in the team to understand and familiarise themselves with the design information. However, this pattern observed to be disrupted whenever limited availability of information needed for informed design decisions was experienced. Participants in the team switched to individual or sub-group mode of viewing design information on restricted devices in cases where relevant aspects of design information appeared to be either readily unavailable or inadequate. In all the meetings observed, situations of insufficient or unavailability of relevant information witnessed changes in the way teams viewed information in the interaction process. This move suggests that participants in the design teams observed seem to consider accomplishment of

collaborative task critical, hence endeavour to make every effort in addressing their information needs.

In related development, the analysis shows that individual and sub-group viewing of design information were largely related to 3D CAD rendering representation, and 2D sketched information which were added in the course of the interaction. These actions appeared to be in response to propositions of alternative design solutions as well its evaluation which were considered necessary in augmenting the existing information. In exploring conversations or collaborations around these variations in viewing as far as the teams' practices were concerned, the study suggests that viewings in singles or sub-groups often attracted queries and explanations as the team seek to evaluate and modify the additional information generated.

Apart from obtaining insight into how viewing of design information emerged and were accomplished in interaction, and the opportunities for collaboration, consequence to the interaction process also attracted analytic interest. While participants in design teams creatively supplemented their information needs via viewing in restricted displays, these nonetheless, altered the workflow in the team significantly (Table 4.3). Introduction of these interventions shifted focus of attention in the team to the object of display until the viewing and its accompanied navigation exercise were exhausted. This development appeared to suggest evidence of a link existing between display media and flow of work in the team. As changes are introduced to aid viewing of displayed information, focus of attention in the team appears to be disrupted. Even though this situation appears to be a drawback to the workflow in the team, arguing from practice lens of using technology in situated work context, what people do with a piece of technology as they engage with it is key to understanding its emergent use. Whenever users engaged with technology in support of their task accomplishment, the consequence is that they will be confronted either to continue working with it, work around it, abandon it or change their modus operandi to achieve their ends (Orlikowski, 2000). The observations of the meeting sessions revealed that participants in the design as part meeting their information visualisation needs often tend to work around the existing displayed media whenever they are constrained as a results of media limitations by creatively supplementing it with mobile devices and traditional papers. This appears to show that the team members observed give much premium to accomplishing the task at hand irrespective of the limitations impose by the media.

Although viewing action in relation to different representations and state of design information were observed to be predominant in the moment-to-moment engagement with the media, its understanding is complexly enshrined in the circumstances leading to its emergence. Hence different dynamics in relation to type, occurrence, and consequence as well as its connectedness to overall actions and activities have appeared to be critical far as its value as resource of interaction is concerned. While the study reveals dynamics in viewing of design information, viewing action appears to shape participation and flow of interaction. Again, the analysis suggests that the action of viewing of design information, irrespective of form, appears to be intertwined with navigation and hand gesturing actions and also utilised as a resource to stimulate conversations in the activity of the design review session witnessed. The non-verbal actions connected with this action as well as verbal engagements facilitated are analysed in detail in subsequent sections.

Summary of the nature of viewing design information in design meetings observed

- Viewing is a ubiquitous non-verbal interaction which heralded and stimulated the undertaken of different design task during the meeting session.
- The design team viewed varying range of information representation to familiarise with content of the design via large displays, mobile devices and paper medium.
- The design team accomplished viewing task through three different approaches, including group viewing, sub-group viewing and individualised viewing during the meeting session.
- Different display feature of the medium incited different approach to view design information as overall group viewing tended to associate with large displays while sub-group and individualised viewing were more aligned to mobile devices (small displays) and paper medium.
- Viewing of design information on large displays incited and sustained dynamic exchanges among the team while mobile devices and paper mediums tended to breakdown the dynamic exchanges ensuing in the team.
- The practice of the design team was first to view together the principal information representation (VR models and 3D CAD renderings) at the commencement of their exchanges, however, switched to view auxiliary information (2D CAD elevations views and detail drawings) relevant to support their tasks as the meeting progresses.
- The design team viewed existing information together on large displays, but transitions to view new information displayed on mobile devices (tablet and smartphones) and paper medium in small groups and individual bases.

4.5.2 Annotating design information

Annotating design information in digital format during design review meetings has been observed to be a predominant activity often undertaken by participants in the design team as they attempt to communicate and develop the evolving design. The premise being that annotation provides opportunity for participants to add extra information to the design thereby contributing to its transformation. This supplementary information often come in the form of explanations, comments and suggestions through which the design team maintains record of the design process and share design knowledge and information to relevant stakeholders in the design project (Lenne et al., 2009; Marshall, 1997). However, annotating design information is seen as a dynamic activity due to its complex structure as well as the context of its emergence.

In designing, annotation is considered as a means whereby visible markings are introduced directly on the information representation and positioned within the context of the shared information (Aubry et al., 2007; Lenne et al., 2009). Hence, annotation encompasses both the marks (the form of annotation), and the informed function (Marshall, 1997, p.94). The form of an annotation comprises the medium with which the information is written; the content, that is the information itself, and the presentation or display of the annotation. In terms of function, annotation marks can serve as a representation of an object, describing an existing structure, or a carrier of meaning (Lenne et al., 2009). Consequently, both the mechanics and utilisation of annotation are key to provide insight into how the design team interacted with information representation through the annotation facilities of technologies in the digital space.

This study operationalises annotation as markings whose target is an information representation and takes its context with reference to this object. This involves line markings, symbols, short notes and sketches participants in the design team add to information representations during the meeting session. The interest of this section concentrates on the exploration of how the design team annotates information representations during design review sessions? Further, the analysis explores the conversations generated around the accomplishment of annotation task. Hence, issues pertaining to: ‘the what’, ‘the when’, ‘the how’, and ‘the why’ of annotation and mark-up actions in relation to information representations are comprehensively addressed in this section.

Annotating information representations was observed to be a predominant non-verbal act in relation to design information during the meeting session. Indeed, annotation did occur with both VR model and the 3D CAD rendering representational media, however, this was more prevalent in the former compared to the later (see Figure 4.21). Annotation was different with different representation of design information (see Figure 4.21). Interesting and important observations were noticed in these variations which tended to shape the flow of work during the meeting session. These distinctions mainly centred on the emergence and accomplishment of the annotation as well as usage.

4.5.2.1 Emergence of annotation in design meetings observed

Annotation varied across different information representations of design in terms of use and structure in the design meetings observed. The analysis reveals that team members consistently used annotation to climax current discussions on design information and ushered in a new task (see Figure 4.21; Excerpt 1 and Excerpt 2). Hence, serving not only as a tool for documenting design decisions, but also in structuring the flow of work in the team.

Figure 4.21: *The design team jointly annotating the digital image of a section of brick wall in the VR model during a design review meeting session.*

Episode 1 (E1), 21st of January 2018

Excerpt 1 [170:045.08 -177:051.12]

170 X: *((Walking through and Viewing the model))*

171 C: Just go around the corner, the dark. Yes.

172 X: *((Virtually walking through the balcony area of the VR model, capturing views, marking up and annotating, and saving files)).*

173 C: *((Pointing to the VR model)).* The wall looks pale. I think that should be an object.

174 A: So, the two drawings that should be looked at.

175 B: *((viewing and pointing to the wall)).* Yeah, that wall dark, that remains dark.

176 C: *((Pointing to the VR model)).* Yeah that is a pier. The external pier remains dark. Let's capture that.

177 A: Alright. That's ok.

Excerpt 1 indicates a case where the design team embarked on annotation activity while concluding discussions on design decisions in the VR model enabled design meeting session. As part of the design review task, the team required to identify potential design problems and propose solutions towards their resolution. Part of the challenge here concerns with choice of brick colour. Designer C raises concern on colour of the external pier of which the team deliberate in addressing it [Lines 171-175]. The team members upon these deliberations reached a consensus on the appropriate colour for the external pier [[175-176]. Consistent with their workflows in the VR model, Designer C then requested for the decision to be captured in the form of annotation [Line 176]. With this practice, the team documented their design decisions and ended discourse on the current issue. This development was observed to be consistent in meetings mediated by the VR model. The orderliness in the use of annotation during the design meeting seemed to aid in structuring the workflows in the team activities during the design meeting since participants exhibited commitment to its usage.

In contrast, annotation with design information in 3D CAD rendering enabled design meetings mainly happened while participants proposed and brainstorm alternatives to design solutions. Whenever there was a need for consideration of different choices to earlier design decisions, the team members provided additional comments and contributions in the form annotations. However, annotation in these situations was observed to be unstructured and inconsistent, since antecedents to their occurrence appeared to be unpredictable as the work flows during the meeting session. An instance of this is illustrated in Figure 4.22 and Excerpt 2.

Figure 4.22. *A participant annotates a 3D CAD rendering via side sketch during a brainstorming session of the design meeting.* ***a****. A participant seek to propose options to the proposed structural design decisions in relation to the transition of the two shapes of the design via annotation while colleagues observe with keen design during a design review session.* ***b.*** *The participant annotates the 3D CAD rendering via side sketch on traditional 2D paper.*

Episode 4, 24th March 2018

Excerpt 2 [215:072.15 -219:074.00]

215 B: *((Pointing to the 3D CAD rendering displayed on the SmartScreen))*. Are these two parts independent structures?

216 A: Yes the two are separate. The walkway and the shell.

216 B: I think the transitions are all difficult. They need to be connected if they are two separate entities. The separate structures need to be connected.

217 C: ((Po*inting to the 3D CAD rendering)).* You can start borrowing from this structure and link with the steel so it will be the continuation of the same structure to avoid the transition problem.

218 B: ((Pointing *to the structure, make drawing like sketches over the area of the virtual model on screen as if providing alternative solution towards resolving the transition problem, moves back and provide sketch on a sheet of paper as contribution to resolving the design challenge)).*

> The idea is to do similar combination of structures where this part bounces to the other. In that case you can reverse to the floor to follow that line and railing just go across there. That will make it lovely. When you do it this way it will make it fit into that so that they will be well connected.

The design team brainstorm on design decisions in connection with separation of two structural forms of the walkway as a results of transition challenges identified (Figure 4.22, and Excerpt 2). Hence, participants were confronted with provided suggestions towards addressing the underlying concern. Participant B as part of contribution to the ensuing discussion, provided alternative suggestion in the form annotation by sketching intended solution on a sheet of paper [Line 219]. The suggestion of different approach to resolving the transitioning problem of the walkway attracted attention of the other members in the team (Figure 4.22). While idea of annotating the 3D CAD rendering representation of the walkway through side sketch intended to provide options in resolving the design challenge, the team members also picked up conversations around it. This seems to also suggest that annotating design information by providing extra sketches served as a shared resource in which conversations among the team members are stimulated. Unlike the VR model mediated design meeting, annotation in this mode of meeting became necessary when the need for generating alternatives to the proposed design solution became relevant. Hence emergence of annotation appears to be informed by the situational needs of the design during the design meeting and their social practices in relation to reviewing design information.

4.5.2.2 How annotation was accomplished in design meetings observed

One of the premises of the study is that the use of technology in practice is emergent and ongoing as users carry out their tasks. Hence, how the team accomplish these activities and actions in relation to design information and supported digital medium becomes relevant to providing insight into its situated use during design meetings. Drawing on this notion, the analysis investigated how the design team accomplish annotation task in the meetings observed. Generally, annotations are of two forms: annotating on design information, and side sketching (Perry and Sanderson, 1998). The study extricated these two types of annotation in relation to their accomplishment similar to Tory et al. (2008, p.65). These distinctions became necessary since the use of digitally-enabled spaces in design review processes has been argued as introducing new dynamics in the annotation processes (Boujut, 2003; Tory et al., 2008). These dynamics in relation to how participants annotate design information are introduced with the anticipation of disrupting the structure and participation in the design meeting.

- *Annotate design information*: annotations in the form of lines, symbols and short notes are applied directly onto the reference object.
- *Side sketch:* annotations in the form of sketches are drawn a little bit away from the target object or on a separate media.

How the design team accomplished annotation act was observed to vary across the different information representations and display medium. Both forms of annotation were accomplished in the VR model enabled meetings, whereas only side sketch annotation was evident in the 3D CAD rendering and SmartScreen display mediated design meeting. These observations appeared to be consistent in all meetings observed. For example, in the case of VR model supported meetings, the analysis revealed two forms of annotation usually accomplished by the team during the meeting sessions. These types of annotation were observed to be direct annotation (i.e. annotate design information), and side sketching.

Interestingly, contrary to design review sessions (Tory et al., 2008), where comments in the form of annotations are done individually, either on the representation of the design information or in writing as contributions towards developing the evolving design, the analysis revealed joint annotation and marked up activity executed by the design team on the VR model via digital image generated (see Excerpt 3). In most of these instances, the annotation and mark-up were carried out collectively by the team, although controlled technically by the team member who doubled as the operator of the VR model. Mainly, the annotator highlights and creates a digital image of the section under consideration through the digital image generation facility of the Enscape plug-in application for Revit architecture. An instance of annotation and mark-up action is illustrated in Figure 4.23 and Excerpt 3 (352:58.26-369: 60.46).

Figure 4.23: *The design team annotating and marking up area of brick wall in VR model via side sketching.*

Episode 2 (E2), 21st of January 2018

Excerpt 3 [348:58.26-369: 60.46]

348 A: *((Pointing to the VR model)).* That is the place leading to the existing model.

349 B: *((Viewing and pointing to the landscape in the VR model)).* Did you extend it to that end?

350 A: Yeah, that is over there. *((Pointing to the VR model)).*

351 C: *((Viewing the VR model)).* It doesn't serve like a return

352 A: Yeah everything in it.

353 B: *((Viewing and pointing to the landscape in the VR model)).* Well in that case anything in the shape then you have will take that side off. You can drop the brick down that side off.

354 A: Yeah that make sense to me. That makes that side nice. *((Marking up and drawing line in the plan area to be resolved)).* Yeah that is the plan area to be resolved.

355 X: *((Creating view, marking up and annotating))*

356 B: *((Pointing to the VR model)).* What is the scale from that end?

357 A: *((Pointing to the wall from that unit)).* Here?

358 B: Yeah

359 A: That is a good question

360 B: *((Viewing and pointing to the VR model*)). So that stair comes from the other level unless you start from the ground

361 C: *((Pointing to the VR model)).* No, that return will not fit

362 B: ok

363 A: *((marking up the area of discussion))*

364 C: Approved. Done

365 X: ((Viewing, capturing views, annotating and marking up))

366 C: Is everything talked captured here?

367 B: Yeah

366 A: *((Viewing, marking up the agreed plan area)).* Is there anything else?

367 C: *((Pointing to the VR model)).* I believe there is a need to reduce the staircase there.

368 A: Yeah, otherwise it sounds that there is some misfixing. *(annotating and marking up the area)).* Do you agree on that?

369 C: No

The design team accomplished annotation activity by first creating a digital photo of the corresponding object under consideration and made 3D line marks, symbols as well as short notes, and sketches depended on the need. These forms of annotation were observed to be accomplished through the Image creation facility and annotation tool of the Enscape plug-in application for Revit architecture. The annotation data, which encompassed both created digital photo, and symbols of representation were saved separately from the VR models, thereby preserving the original design. While the team displayed commitment in providing additional information towards developing the evolving design, preserving the originality of the design seemed to be essential in their workflow. Moreover, the act of annotation in the VR model environment appeared to trigger other actions such as object creation, navigation and documentation of design decisions in the interaction process. This tends to suggest that interaction process in the design team appeared to be a complex act since accomplishment of a single act rely on interlinkages with other actions for its meaningful realisation.

4.5.2.3 Techniques in annotating design information

Although, the data revealed separation of annotated object from the VR model via the generated digital photos, mode of application on the target object were seen to vary, mainly in terms of structure and level of detail. Annotations in simple structure and detail such as question marks, line marks and short notes were attached to the created digital image and saved accordingly (see Figure 4.22). Conversely, annotations in the form of sketches which were observed to be comprehensive, both in representation and information detail, were isolated from the corresponding object (see Figure 4.22 and Excerpt 4). The positioning of the side sketch annotation seems to relate to translation of the design object's current position. In another development, some linkages were observed to exist in both the structure, and accomplishment of annotation as well as participants' participation. Simple annotations were accomplished quickly by the team whereas complex annotations happened after extensive deliberations among the team members. Although ample time and effort were dispensed in the completion of complex annotations, rich contributions towards its accomplishment emanated from individual team members. These contributions were in the form of comments, suggestions and queries. The indication is that while design team employed annotation as a resource in contributing to the design development, its accomplishment appeared to have engendered collective working among the team since ample discussions surrounded their accomplishments.

Whiles discrepancies are claimed to be sometimes existing between the envisioned use, and actual use of a novel technology (Orlikowski, 2000), examining how a given action in relation to the media is accomplished in-situ is imperative to understanding the dynamics of its emergent use in practice. The analysis revealed interesting observations in the act of annotation and actual use of annotation facility in the digital space. From the observations, while annotation of design information in the virtual walkthrough model representation was done via the digital photo generated, thus preserving the integrity of the original design information. The analysis reveals some evidence of constitution of structures towards situated use of the annotation functionality afforded by the Enscape plug-in for application Revit architecture. Although the media application was delivered with enhanced annotation and mark-up functionality thereby enabling inscription of annotation and mark-ups on the virtual walkthrough model, the analysis revealed otherwise. The design team did not apply annotations directly on the virtual model, instead created a digital photo of the specific area via the image generation capability of the model before annotating. While the digital application media was enriched with annotation and mark-up functionality, a novelty key in virtual walkthrough mediated space, their social practice of preserving originality of design information in review meetings appeared to shape how the annotation facility was used in practice. The interpretation could be that, while the team underscore the importance of changing their innovation practice via 3D mediating process, disruptions to workflows and design review processes were also adhered to. Another implication the analysis revealed is that, while the media had specific facilities to support collaborative task such as annotation, the actual utilisation of the facility appeared to be under the discretion of the team as well as the prevailing conditions of work practice.

4.5.2.4 Use of annotation in the meetings observed

Interestingly, while the annotation is being accomplished, the team picked up conversations around the mark-ups, sketches and specific details captured in the image. Hence, the act of annotation and mark-up appeared to serve a dual function in this instance (see Excerpt 5). First, annotating and marking up the model via the generated image provided additional information relevant to modify the current design. Secondly, the team picked up conversations in the form of comments and questions relating to the nature of the annotations and mark-ups produced as well as details captured in the photo. Interestingly, discussions around the annotations contributed to the nature and details covered in the annotation exercise, thereby appeared to have enriched the details of the extra information conveyed by the annotation. Although the technical operation of the annotation and mark-up exercise was controlled by the facilitator, the observation revealed evidence of collective involvement by the rest of the team members. The nature of the participation happened to be in the form of contributions and questions in relation to the nature and details contained in the annotations created. An instance of this is exemplified in lines 179 to 181 of Excerpt 5:

Episode 1 (E1), 21st of January 2018

Excerpt 5 [179: 054.00-181:055.15]

179 D: These photos are very well captured.

180 B: That’s nice. So, Richard when are you going to see them?

181 A: ((Busily annotating the captured digital image and saving it)) Yeah possibly next week.

This instance illustrates a typical annotation activity in the VR model enabled design meeting and the conversations generated. As part of the workflows of the design team in the digitally-enabled design review process, the team annotates the design information to finalise deliberations on the colour of the brick pier. While the annotator (Participant A) carries out the annotation activity via generation of digital photos, Participant ‘D’ provides a comment in admiration of the generated digital photo [Line 179]. This comment also attracted the attention of Participant ‘B’, with an attendant contribution (Line 180). By these acts, Participants ‘D’ and ‘B’ entered into and participated in the ongoing activity, although manipulated by Participant ‘A’. Similarly, participants in the team used the occasion of annotation for other conversations in relation to their personal needs. For instance, in Line 180, Participant ‘B’ enquired about when Participant ‘A’ intends attending to a social issue they had previously picked up conversations on. These conversations tended to balance the team’s task accomplishment with their socio-emotional needs.

From these instances, although the annotation activity was manipulated by a single person, its accomplishment appeared to be collaboratively achieved, partly due its handling as well as the distinctiveness of the markings, and curiosity on the part of the participants in the captured photos. Indeed, the act of annotating design information in the virtual walkthrough model gained members attention, since it generated interesting remarks and conversations, both in terms of project goals and personal needs. Hence, while the design team used annotation to summarise, document and communicate design information towards attaining the project goals, it also provided forum for maintaining the teams’ wellbeing. However, this was observed to be more frequently with the virtual walkthrough model compared to the 3D CAD rendering enabled design meeting. This observation tends to buttress the need maintaining a balance between goal-oriented task, and socio-emotional act in the interaction process, since the overconcentration of one poses a strain on other (Bales, 1950). Surprisingly, this nature of interactive activity consistently emerged whenever the act of annotation in the interaction process was undertaking.

In concert with analytic orientation of the study, analysis of annotation and mark-up act facilitated by the Enscape plug-in application for Revit architecture was examined to gain insight into how the resource was utilised in interaction to support collaborative working in the team. The analysis revealed that the process of accomplishing annotation act in the design meeting significantly contributed to the team's participation structure. In most of these instances, the team members picked up conversations about the remarks and additional suggestions captured in the form of annotations and mark-ups to reach common ground whilst the mark-up, sketches and annotation activities unfolds. Interestingly, the conversations stimulated around the comments accompanying the mark-up further appeared to redirect the nature and details of subsequent markings in the interaction process. From the observations, the annotation and mark-up did not only function as a non-verbal action with the virtual walkthrough model, but also as a means of directing conversations centrally to the underlying digital photo. Hence, the annotation, coupled with the image creation activity, served as a stimulant or object of discussion for the team. Further, the conversations informed the nature and details of subsequent markings and annotations on the corresponding digital photo. While the annotation and mark-up action served as a resource in generating extra information toward transforming the current status of the design, the analysis reveals evidence of team engagement facilitated by the act.

Summary of annotating and marking-up design information in design meetings observed

- The design team carried out annotation task mainly to summarise and document design decisions, however, contributed to shape the team's workflows and stimulated interpersonal discussions among the team members.
- The design team collaboratively accomplished annotation task, however, technical operation executed by a sole person (annotator) in the VR model supported medium.
- Annotation in the VR model was applied on a digital copy of the design information separately from the original information representation via the image creation and annotation tools of the Enscape plug-in for Revit architecture.
- The design team employed two different forms of annotation, including direct annotation and side-sketch to capture and record design decisions during the meeting session.
- The use of annotation served a dual purpose in the term's workflow, including addition of new information to modify the existing design, and inciting dynamic exchanges among the team members in relation to structure of the annotation object.

4.5.3 Navigating design information

Design teams in their quest to accomplish a collaborative task in design review meetings supported by digital spaces are often confronted with the need to utilise wide range of design information. From analytical orientation of this study, digital spaces are argued as heterogeneous and dynamic in nature, hence design information emerge in different representations and level of detail to shape the activities of the team. This information is either provided a priori or emanate unanticipated in the course of the meeting, making information availability unpredictable and a complex endeavour to grapple with. The design team thus are required to harness and incorporate these bits and pieces of information into a coherent whole to realise their collaborative task. Hence, how participants navigate in these varying information representations and sources for relevant details becomes critical in this direction. Navigation is considered in this study as the process whereby participants in the design team locate and interact with relevant information in design representations to support their deliberations. Typically, the section presents analysis on circumstances necessitated for emergence of navigation task ("the when of navigation"), navigation with information representations as well as accomplishment of navigation ("the how of navigation").

4.5.3.1 Purpose of use of navigation in design meetings observed

Navigation was observed as an important non-verbal act team member engaged in to meet their information needs during the meeting session. The analysis revealed that participants often navigate various representations of design information to support variety of their goals. First, the team members relied on navigation to search for and relate different aspects of information while describing and explaining design rationales during the meeting session. Second, navigation was also carried out when the design team required to add annotation and mark- up to specific portions of digital photos generated during the meeting session (see explication on annotation in section 4.6.1). Third, the team embarked on navigation task to query, evaluate and use varying amount of information in relevant detail while engaging in conversations around the design. The quest to interact with relevant aspects of the design information in varying representations while performing specific task was observed to engender conversations towards understanding and developing the existing design. For example, in one of the meeting sessions within the VR model mediated space, participants needed to explore content of the VR model and engage with relevant details of the information. While interacting with content of the model, the demand to pick up conversations about specific aspects of the design became necessary to understand and develop the design (see Excerpt 1).

Episode 5 (E5), 24th of May 2018

Excerpt 1 [406:070.30-413:072.45]

C406: Can we inspect content of Block 'D' as well?

A407: *((Virtually flying and walking through the model to inspect elements in the 3D model))*

C408: ((Viewing and pointing to the wall panel)). Where are these panels from? That end it was fixed initially.

B409: *((Pointing to the panel)).* It is on top of that one.

A410: Because that is fixed onto that concrete slab ((Pointing to the part connecting the panel and concrete slab)). That concrete should have been a bit stand alone.

B410: No.

A411: Because that should have come forward.

B412: Yeah, it is forward and blunt, but into the building. So, there is angles on the other side of the bar.

A413: Ok. That is good *((Annotate and mark up the portion of the panel))*.

Excerpt 1 illustrates an instance in which the team members attempted to explore and obtain a general overview of the current state of the design as represented in the virtual reality (VR) model. Besides, the team needed to inspect the various features of the model for potential errors and provide recommendations to address the discrepancies. Consistent with their practice in reviewing design information in the VR model mediated space, Participant ‘C’, in line 406 (Excerpt 1) suggests, “Can we inspect content of Block ‘D’ as well?” The suggestion to explore content of design information in 'Block D’, requires that the team virtually perform series of ‘fly’ and ‘walk’ through operations in order to inspect both the exterior and interior content of the model. Consequently, by relying on the fly through and walkthrough functionalities of the Enscape plugin Revit Architectural application, Participant ‘A’, who doubles as the navigator, first fly through the model virtually using the mouse and keyboard controls to locate Block ‘D’ as requested, and then switched to walkthrough mode to enable the team inspect the interior elements of the model (Lines 407 and 408, Excerpt 1).

While the navigator performed flythrough and walkthrough operations, participants viewed features of the design as projected on the wall screen and initiated conversations on design issues identified. In line 408 (Excerpt 1), Participant ‘C’, picked up issue with the position of the wall panel by asking, “Where are these panels from? That end was fixed initially.” With this remark, Participant ‘C’ appears not to understand the position of the panel object. The issue about position of the wall panel stimulated conversations among the team members. Participant ‘B’, in contributing to aid understanding of the panel wall position (Line 409, Excerpt 1) provided description, "It is on top of that one” by pointing to the related concrete slab. Contrary, while participant ‘B’ described position of the panel in response to earlier concern, Participant ‘A’ in lines 410 and 412 (Excerpt 1) appears to disagree by suggesting: “That concrete should have been a bit stand alone.” In attempting to provide clarity to his assertion, Participant ‘A’ further proceeded to explain rationale underpinning his argument: “Because that is fixed onto that concrete slab” and “Because that should have come forward” (Lines 410 and 412, Excerpt 1). The descriptions and follow up explanations around the position of the wall panel seems to enhance clarity about the situation. Although Participant ‘B’ appears to disagree with Participant ‘A’ remark that the concrete slab in which the panel is connected needs to be an isolated structure, she affirmed the part of the explanation “... that should have come forward” by contributing with further explanation “Yeah, it is forward and blunt, but into the building; so, there is angles on the other side of the bar.” Consequently, Participant ‘A’, in line 413 (excerpt 1), adds “Ok. That is good”, suggesting that he finally agrees with the position that the panel wall be fixed to the concrete and tilted a bit forward. Further, Participant ‘A’, in line 413 (excerpt 1), via the photo generation and 3D annotation and mark-up functionalities of the Enscape plugin Revit architectural application, proceeds to create a digital photo of the panel under discussion and annotated with 3D markings to summarise and communicate the team’s recommendations on the location of the wall panel. By following up to create and add the annotation markings, the team appears to suggest that they have mutually agreed in understanding the appropriate position of the wall panel.

These instances point how performing the navigation task in the VR model emerged in response to participants' goal of obtaining general overview and interacting with specific aspect of the design. Further, auditing content of the VR model for discrepancies engendered undertaking of relevant task such as describing and explaining the design as well as creating and annotating the required recommendations. By stimulating conversations around the design, interrogating and looking up design information appear to be intertwined with task related to understanding and developing content of the evolving design.

4.5.3.2 Techniques in navigating information representations

The design team employed variety of techniques to navigate information in design representations during the meeting session. The analysis revealed that navigation varied across different representations and display medium, and that each technique shaped the way the team members interacted with the information. The categorisation of navigation techniques across different information representations are presented in Table 4.4.

Table 4.4 Navigation techniques with information representations in display media

General description	**Specific goals**	**Examples**	**Information representation**	**Display medium**
View set-up				
Zoom/ rotate/ orbit/ pan: to alter the size, position or current view of design information.	Engage with specific details of design information for focused discussion.	Section of VR model was orbited to show different relevant views. See Fig. 1c Participants zoomed in and panned to view relevant portion of information	VR model, 3D CAD renderings; Video data	Enscape Plug-in Revit Architecture application; BIM space, Wall display; SmartScreen in PowerPoint

	Add annotation and mark-up to generated digital photos.	displayed on Smartphone. See Fig. 2 Navigator zoomed in and panned to add annotation and mark-up to generated digital photos.		application; Mobile devices (Smart phones and Tablets)
Walkthrough: move through the VR model to access interior details of the design.	Relate information; Engage with specific detail of information; Explore content of design information.	Participants moved through the VR model to inspect element layout of a kitchen.	VR model	Enscape Plug-in Revit Architecture application; Wall display, BIMspace
Flythrough: move around and over VR model to access interior and exterior details of design.	Experience overview of design information; Relate information; Interrogate design information.	Participants fly through the model to interrogate objects on roof top. See Fig. 1a	VR model	Enscape Plug-in Revit Architecture application; Wall display, BIMspace

Source: Author's field work (video data), 2018)

Table 4.4 illustrates various navigation techniques the team employed to accomplish specific goals in relation to design information within a display medium in a meeting section. Navigation act seems to be more compelling in the VR model compared to other types of representations (Table 4.4). All the navigation techniques, including virtual walkthrough and flythrough, zooming as well as orbiting were noticed in the VR model representation while the team attempted to accomplish specific goals in relation to the design. For instance, the design team had to employ fly through, zooming and orbiting techniques to explore and engage with roof and landscape details while discussing exterior content of the VR model (Figure 4.24).

Figure 4.24. *Navigation VR model with different navigation techniques.* ***a*** *Flying through the VR model to explore exterior content of the design.* ***b*** *Zooming in for wider view of exterior content of design.* ***c*** *Orbiting to adjust external details of the model for correct perspective.*

Figure 4.24 indicates various techniques the design team employed to interact with exterior content of the VR model via the Enscape plug-in Revit architecture application on the wall display screen. The VR models allow users to 'walk' and 'fly' through the design to experience its interior and exterior contents. The team wanted to explore content of the model for potential errors and propose recommendations towards their resolutions during a meeting session. To accomplish this, the navigator in conjunction with other participants virtually fly and walkthrough the design using the walkthrough/flythrough functionalities of the Enscape plugin Revit architecture application. While flying and walking through the model, the navigator identified some objects installed on top of a roof, as shown in Figure 4.24a, and remarked, "What is that?". Once the object is located, he then zooms in using the 'Zoom In' tool via the mouse and keyboard control to focus on the item (Figure 4.24b). While a proper perspective of the item is obtained, a participant responded to the earlier concern, “They are safety items incorporated on the roof.” In seeking to obtain clarification of the decision, another member queried, “Do we need a roof safety item on the roof?” The identification and installation of the roof safety item generated further conversations among the team members of its relevance in relation to the roof’s function. In another instance, an exterior section of the model with a landscape was zoomed in and orbited for adequate view to enable the team resolve issues on appropriateness of the landscape (Figure 4.24c). Upon obtaining accurate view of the landscape in question, the navigator initiated a conversation by remarking, “...the landscape transitioning from one colour to another, obviously work from an angle which is by the upper, and so trying to get rid of.” By this, he challenged the choice of landscape around the area of the model under consideration. In this instance, the design team, do not merely engage the design object at different views, but take into consideration view of the element as they are manipulated. Consequently, the manipulated views served as a resource, for example, to inform the nature of conversations initiated around the content of the design object. Hence, each activity in navigating the virtual reality model is embedded in the prior.

In contrast to VR model, minimal navigation was observed in information representations such as 3D CAD renderings during the design meeting (Table 4.4). The design team employed view set-up techniques such as zooming, rotating, orbiting and panning to support discussions of varying exterior details of the design depending on situated need of the task. Navigating the information representation via view set-up techniques ensured that the team focus conversations around relevant details or add annotation and mark up to specific aspect of the design. For example, in a meeting to review design decision on 3D CAD rendering of a walkway, the lead architect occasionally rotated, zoomed in and out the model using the mouse control to aid discussions on structural arrangements of the design (Figure 4.25).

Figure 4.25. *Navigation 3D CAD rendering with different navigation techniques.* ***a*** *Zooming out the 3D CAD rendering to provide overview exterior content of the design.* ***b*** *Zooming in to limit discussion on specific detail of the design.*

Figure 2.25 exemplifies navigation with the 3D CAD rendering, where different view set-up techniques were employed to assist the team interact with specific details of the design during a meeting session in the SmartScreen display mediated space. The 3D CAD rendering had the capability to reveal both the 3D geometry as well as the visual characteristics such as texture and shade to make proposed building more realistic. In this instance, the team were evaluating appropriateness of the structural arrangement of the walkway. In line with the discussions, a participant while taking a turn, requested "Can you adjust the model to highlight the base of the structure, the v-column and the tripods in relation to the form and the railing". In response to the participant's request, the lead architect, who doubled as the navigator, zoomed out the model using the mouse control to bring into view the requested details (Figure 4.25a). Once the aspects of the walkway in question are revealed, the participant remarked "the base of the structure is questionable if you consider its connection with the railing and the rest stop, however, I think the v-column can be modified to provide stability to the entire structure". Consequently, the participant continues with further request, "Can you provide full view of the v-column section of the structure". The navigator proceeds to zoom in the model and focus the v-column into perspective (Figure 4.25b). While the navigator zooms in the model to display the v-column area of the walkway, the participant then provides a suggestion, “the combination of structure where one curve bounces the next, so they push together against each other. The fact is each member is getting fatter at the middle because it is not supported by others. If that two tripods reverse, they will be getting thinner if they are not connected, and that might work in this instance”. In this case, the navigator had to adjust the view via zooming out and zooming in techniques to enable the participant to understand the structural decision in relation to the general framework of the walkway as well as details of the interconnected members, thereby informing suggestions toward their modifications. This fragment has shown that the demand to employ specific view set-up navigation techniques such as zooming in and zooming out in relation to the 3D CAD rendering appeared to be connected to the team’s specific goals within the context of the content of the design information.

Although navigation with 3D CAD view was sparse, it was observed to be different in terms of purpose compared to the 3D CAD rendering. Specifically, the design team navigated 3D CAD views as a follow up to prior deliberations on specific content of the VR model. Hence, navigating 3D CAD was observed as an extension of VR model to address specific concerns. For example, in a discussion to recommend suitable rendered colour for a brick wall within the VR model, a participant requested for wider display of the 3D CAD view, where varying wall types have been shaded with different colours. The 3D CAD view provided opportunity for users to experience aspects of exterior and elevation of the brick wall, and aid description of their details. To realise this, the navigator switched to load the specific 3D CAD view on the wall display screen (Figure 4.26a). Once the required view is projected, the navigator zoomed in to provide adequate view of the wall types and their shaded colours to support discussions of appropriate colours for each wall type (Figure 4.26b). In this case (Figure 4.26), the decision to navigate the 3D CAD view was necessitated as a result of specific information needs on wall types and rendered colours required to supplement content of the brick wall as contained in the VR model.

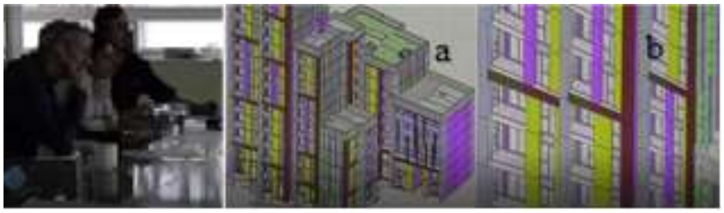


Figure 4.26. *Navigation in 2D CAD view.* ***a*** *Loading to display the 2D CAD view of the south wall types of the proposed building.* ***b*** *Zooming in for wider view of wall types with their shaded colours.*

These instances on navigating information representations have shown that while the design team use various techniques to interact with information representations, the type of technique employed tends to align with nature and content of the representation as well as the specific discussions engaged in relation to the design.

4.5.3.3 How navigation was accomplished across display medium

Navigation was performed as a collaborative activity, however, varied across some digital spaces in the meetings observed. Participants worked together by providing inputs in the form of technical skills and verbal suggestions to realise the navigation task. The main difference centred on navigations around mobile devices (smart phone, tablets) compared to other spaces such as BIMSpace, Wall and SmartScreen display media. An example of how the design team accomplished navigation task in the Wall display mediated space is presented in Excerpt 2 while that of mobile devices is shown in Figure 4.27.

Episode 2 (E2), 21st of January 2018

Excerpt 2 [371:062. 30-383:066.45]

X371: *((The navigator virtually walking through spaces in the model via keyboard and mouse control while the other team members watch with keen interest))*

A372: *((Inspecting the space, pointing to the 3D Enscape virtual model and asking question)).* So, what is this dimension here for? This is the top of craft. No, it is not, it has nothing to do with it.

D373: It is the top of the office.

B374: I don't see that as office.

C375: Can we move to that place to look at it properly?

X376: *((The navigator virtually walking through the corridor into the space under discussion))*

C377: So, this is another space? *((Pointing to the 3D Enscape virtual model))*

B378: Yeah, that is the end of stair.

X379: *((Virtually walking through the spaces in the model))*

B380: *Can you take us to the other end to enable us look at the stair out there?*

A381: *((Pointing to the 3D Enscape virtual model)). Which part? This end.*

B382*: ((Pointing to the exact portion of the stair in question)). No the other part. Yes, other stair.*

A383*: ((Virtually walking towards the staircase to locate the exact portion of the stair in interior space of the virtual walkthrough model))*

Excerpt 2 reveals how the team accomplished a navigation task in the VR model displayed on the wall screen. The extract gives an instance in which the design team worked together collectively to experience the design information. The design team attempted to interrogate interior details of the VR model to address discrepancies in the design decisions. To realise this, the design team needed to combine both walkthrough and fly through techniques to virtually move through the model and access its content. Participant 'A' performed technical operations of virtually moving through the VR model. While Participant 'A' virtually walks through the model in lines 317 and 372 (Excerpt 2), he initiates a conversation with a query around placement of dimension on the craft object, "So what is this dimension here for?" The concern about dimension of the craft object stimulated discussions among the participants. In line 373 (Excerpt 2), Participant 'D' contributing to the conversation, responded with a description, "It is the top of the office." However, while participant 'D' understands the object in question as the top of the office, Participant 'B' in line 374 (Excerpt 2), considers otherwise, "I don't see that as office". While resolving the disagreement, Participant 'C' in line 375 (Excerpt 2) suggests by pointing to the VR model displayed on the wall screen, "Can we move to that place to look at it properly?”. The request for further navigation was to obtain further details about feature of the design and assist in examining nature of the interior space under discussion. Consequently, the navigator via the mouse and keyboard controls, virtually walked through the model to the desired location, zoomed in and orbited the required segment of information for adequate viewing [Line X376, Excerpt 2]. While the navigator performs the navigation exercise, other participants in lines 377 and 378 (Excerpt 2) contributed to the operation by directing attention to the desired object location, “... this is another space”; “Yeah, that is end of stair” [Line 382]. In this instance, although technical manipulations to virtually move through the model was handled by Participant ‘A’, other team members supported the process by offering suggestions to direct the navigator’s attention to the required location of design information. Hence, ensuring that relevant aspect of craft object information needed to inform their discussions are obtained. This has shown that the design team approached navigation within the Wall displayed mediated space as a collective exercise whereby both technical operations as well as members’ suggestions are utilised to access and interact with relevant information for informed design decisions.

4.5.3.4 Navigation in mobile devices

In contrast to navigation in the wall display mediated space, navigation around mobile devices was accomplished in turns, however, collaborated around transfer of the device. By grabbing or releasing the mobile device each member had opportunity to participate in the navigation activity. An instance of how the design team accomplished navigation with the mobile device during a meeting session is shown in Figure 4.27.

Figure 4.27. *Participant taking a turn to navigate design information on tablet during a meeting session.*

Figure 4.27 exemplifies how the design team accomplished navigation task on a tablet display during a meeting session supported by the VR model and the wall display space. In this instance, the team were resolving issues on suitability of choice of landscape material for specific section of the building. A participant via a tablet device had additional information on landscape materials which needed to be shared to support the discussion. To interrogate the information, participants had to manipulate the view using zooming, rotating and panning techniques. Consequently, the participant passed the tablet on to other members to interact with the information. Each member in the in team is provided opportunity to interact with the information on the tablet display. Upon receiving the tablet, the current participant took a turn to navigate and view relevant aspect of the information on the screen via panning, zooming and rotating with the hand touch. In this instance, the technical operation involved in navigating the information on tablet screen is accomplished individually. While a member takes a turn to manipulate information on the tablet screen, other participants engaged in miscellaneous conversations either on the project or personal. By moving the tablet round, prior conversations around the landscape object is halted to allow active participation of members in the navigation activity. Hence, facilitating collaboration among the team members in accomplishing the navigation task. This instance has shown that the design team perform technical operation of navigation around the mobile device in turns, however, collaborate through the tablet movement to successfully realise the navigation task.

4.5.3.5 Bottlenecks in navigation task observed

Navigation experienced occasional bottlenecks in the 3D CAD rendering mediated design meetings. Although rare, the bottleneck significantly shaped the flow of interaction in relation to use of information, nature of conversations and members participation. For instance, in one of the meeting sessions, the navigator encountered difficulty while navigating the 3D CAD rendering for better detail of the information (see Excerpt 3 [016: 36-018:45]).

Episode 4 (E4), 24th of March 2018

Excerpt 3 [021:016. 36-033:018.45]

A021: The key points we concluded in connection with the railing material and the galvanised structure are that of the issue of standards. ((Browsing through the data and manipulating the 3D CAD rendering with the mouse control for specific view of the model)).

((Participant 'A' struggling in displaying required view of the data as needed. … Dataset already on display disappears from the screen… The project Architect makes another effort to restore the views but unsuccessful. Participant 'A' quickly drops down the mouse control, abandons the search action in restoring the dataset as well as use of the 3D CAD rendering momentarily. The navigator reaches out to a 2D paper version of the elevation on the working table to aid in explaining rationale of choosing the railing material while team members look on with amazement))

C022: I think the conversation is such that we need deeper discussions which are more directional.

D024: I think the steel rail we viewed earlier there looks quite misleading. This view is also not given us much information. Isn't it?

A025: Yeah.

D026: It look like solid stuff.

F027: You can see them through the transparent. Isn't it? So, it's not like inferior solid. But you have got the video version of the Enscape model in there, isn't it?

G028: We have been in the model before. When you go down that high you don't really read anything solid. It seems like the image is misleading.

C029: So yeah, I do agree with this image. I think it is misleading

D030: Can we look at the video version of the walkway for clarification.

A03: The project architect, who doubles as the navigator browse through files in the folder to load the required video version of the walkway as requested.

X 032: *((The team members viewing the video version of the walkway displayed on the SmartScreen))*

C 033: Yeah, I think that is a clearer now.

Excerpt 3 exemplifies a situation where the design team experienced a challenge while navigating the 3D CAD rendering information representation during a design meeting session. In excerpt 3, the design team attempted to resolve misunderstandings regarding design decisions on choice and sizing of railing material for the walkway. This required them to obtain enough information and clarity on the components in question to enable them resolve issues. Part of the concern here has to do with obtaining a better view of the geometry and visual characteristics of the component. Participant 'A', who doubles as project architect navigates the 3D CAD rendering of the walkway to display railing component and elaborate on design decisions in relation to shape, size and material characteristics for informed discussions [Line 023, Excerpt 3]. While attempting to set up correct view of the railing component via the mouse control and zooming technique, the navigator encounters a challenge in displaying the required view as well as maintain prior displayed rendered model on the screen. Consequently, the navigator abandons the search and display action, reaches out to a 2D paper detailed drawing of the element to aid explanation of rationales underpinning the decision. However, the 2D paper detailed drawing was found limited in revealing relevant details of the object's geometry and visual display. Accordingly, Participant 'C' in line 022 (Excerpt 3) remarked, "I think the conversation is such that we need deeper discussions which are more directional". By this, Participant 'C' considers the decision on selecting suitable material for the railing component critical to satisfying the structural integrity of the design. In addressing limitations of information content in the 2D paper detailed drawing, Participant 'D' in lines 23 and 30 (Excerpt 3) suggests for further navigation action in line with information needs of the task, "... This 2D view is not given us much information..." and "can we look at the video version of the walkway model for clarification". Like any other design element in a 3D CAD rendering, the geometry of the object as well as its visual display are essential to examining appropriateness of the design decision (Gul, 2014). As demand for relevant information on railing component appeared critical to the team's deliberations, Participant 'A' browses through the files and opened the video version of the design information. The team appeared to consider data in the video format more informative and less navigable compared to the other representations. Although per their digital practice, the team relied more on use of 3D CAD rendering to aid conversations around the railing component, use of conventional 2D paper detail drawing became necessary in this circumstance. While use of the 2D paper detail drawing was considered an alternative in facilitating resolution of the design issues, its inadequate information content necessitated further navigation operations for richer information presented in the video format. Accordingly, the team had to adjust their workflows in terms of nature and content of information representation to maintain flow of interaction during the meeting session.

The foregoing instance has shown how the design team encountered bottlenecks while navigating 3D CAD rendering and how the development structured the interaction flow and use of information representation. Further, it suggests evidence of an interplay between dynamics in navigation operation and information representation utilised, since conditions of one appear to trigger emergence of the other. Moreover, the instance has revealed how the design team coped with navigation challenges by abandoning information representation momentarily for alternatives considered less navigation demanding, however, richer in information content to support accomplishment of their task.

Summary of navigating design information in design meetings observed

- The design team employed navigation to enable them team search and compare design information as well as describe, explain, evaluate and query design information during the meeting session.
- Navigation task was accomplished through different techniques, including virtual walkthrough, flythrough and view setup via walkthrough/ flythrough, manipulation as well as touch and mouse/keyboard input capabilities of the medium.
- Navigation in VR model was more extensive compared to the CAD rendering SmartScreen medium as the team employed all the navigate techniques to engage with varying details of the design information.
- There was minimal navigation with the 3D CAD rendering representation displayed on the SmartScreen medium in terms of variety of navigation techniques, however, incited and sustained a lot of dynamic exchanges among the participants as individuals gained manipulative control of design content onscreen via the touch input of the medium.
- Navigation was performed as a collaborative activity in the VR model supported interactions as participants worked together providing different inputs (technical skills and verbal suggestions) to execute the navigation task.
- Navigating design information displayed on mobile devices was accomplished in turns, however, the team collaboration through the tablet movement.

4.5.4 Gesturing

This section analysis how the design team employed gestures, as a non-verbal action to interact and engage with design information while accomplishing a task in the design meeting. Consistent with analytic orientation of the study, the analysis examines and explicates the dynamics in gestural actions employed in relation to design information: types of gestures, purpose of use, emergence and accomplishment, and interplay with other types of interactions in the meeting session. The study operationalised gesturing as movement of the hand demonstrating action or depicting spatial data, either remotely or directly, in relation to design information, similar to Murphy (2005) and Tory et al. (2008) characterisation.

4.5.4.1 Purpose of use of gestures

Gesturing was observed to be a predominant nonverbal action with which the team members interact with media and design information. Typically, gestures served to direct/capture attention, relate design elements, represent information, describe and explain design element while engaging in conversations around the design. By directing attention to design information, participants often used gestures to limit conversations on design information to specific aspects being described, evaluated or queried. For example, a participant gestured by touching the virtual model (VR) model of a building displayed on a wall to direct attention to railing element while clarifying earlier concern "…What he is saying is that we show there and it needs to be going there …" to the team members during a design meeting. In this case, the participant interspersed gesturing via touching with verbal descriptions to elaborate on the direction of the railing member.

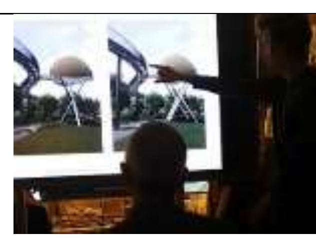
Similarly, gesturing was used extensively to relate elements in the design during the design meeting. In some occasions, the design team needed to relate aspects of design information for comparison to ensure harmony in spatial relations. For instance, a designer used two pens to gesture interchangeably on the form of the shell and the vertical structure of the 3D CAD rendering version of a walkway while providing a suggestion modification in tripod of the support structure as shown in Figure 4.28.

Figure 4.28. *A designer pointing with pen on three-dimensional (3D) CAD rendering of a walkway to relate aspects of the shell structure during a meeting session.*

4.5.4.2 Types of gestures with design information observed

The analysis revealed different kinds of gestures employed to interact with design information and media during the meeting sessions. These types identified gestures unique in appearance and use in relation to design information. Table 4.5 presents analysis of the types of gestures with examples in relation to design information observed in the design meetings.

Table 4.5: Types of gestures with design information that was observed.

Gesture	General description	Example	
Pointing	Use a hand, finger, or pen to point directly or touch the media or a specific part of the content.	A lead architect pointed directly to particular portion of the design to provide targeted description and explanation of rationale behind choice of design decision in relation to form of design.	
Two-finger indication	Use two fingers (usually a thumb and another finger) to indicate the space or	A designer with forefinger and thumb pointed directly on design information represented in 3D CAD rendering format to indicate	

	length between them.	and explain size of a design component.	
Parallel indication	Place both hands, spread apart, and in parallel to indicate the space, size or distance.	A designer indicated the width of a concrete beam using two hands, explaining that the size will be enough to support the roof load.	
Interlocked indication	Use the two hands, partially or fully interlocked, and opposite direction to indicate connection of structural components.	A designer demonstrates to the team how the propose suggestion of tilting base of the shell will fit to the vertical structure of the walkway provide stability upturning the right hand in a cupped shape and partially joining to the left hand, to indicate how base of the shell will fit into the vertical structure, saying, "…if the base of the shell is tilted slightly, it will connect well with the head of the vertical structure, thus maintaining stability …"	

Source: Author's field work (video data), 2018)

Table 4.5 indicates various types of gestures the team members employed to interact with design information while performing a task in the meeting session. The most common types of gestures noticed included pointing, two-finger indication (thumb and forefinger), parallel indication (two up-turned hands in parallel), and interlock indication (a two-hand in locked position) (Table 4.5). Pointing was observed to be a predominant type of gesture used to reference design information during the meeting session. It involves using the hand, forefinger or pen to point to a display media while engaging content of the design. Pointing gestures seemed to be mostly important for referencing information while participants describe and explain design rationales. Besides, it served to direct participants' attention to specific aspect of the design to enable participants discuss or query design information. For example, when discussing form of the shell component of the walkway, the lead architect pointed with fore finger to specific aspect of the shell structure to direct the team's attention while explaining rationale of her decision.

On few occasions, specifically, in VR model mediated meetings, pointing gestures assisted the team to locate relevant targets during navigation. For instance, a participant following his suggestion for further interrogation of a particular staircase in the VR model displayed on wall media, pointed with the fore finger bent on the staircase in question to assist the navigator locate specific area for interrogation during a meeting session as shown in Figure 4.29.

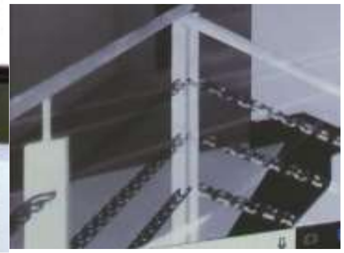
 

Figure 4.29. *A team member pointing with fore finger to direct navigation during a meeting session in the VR model mediated space.*

In contrast to pointing gestures, parallel indication gestures (gesturing with two hands spread in parallel) seemed to be predominantly useful for describing spatial relations of design elements. In describing and explaining rationales of proposed design solutions, participants often gestured with their two hands to indicate size, width or distance of spatial objects during the meeting session. For example, a designer in a meeting session indicated the width of a concrete beam using two hands, explaining that the size will be enough to support the roof load as illustrated in Figure 4.30.

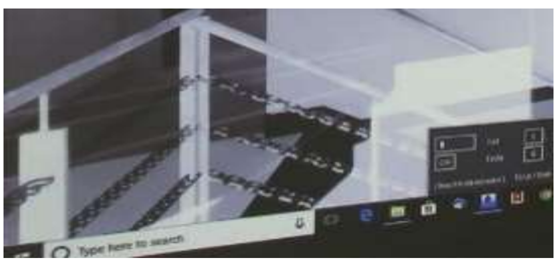


Figure 4.30. *A designer gesturing with two hands in parallel position indicate size of a spatial object during a meeting session.*

In the case of interlock indication gestures, participants gestured to demonstrate connection of structural components or interconnected members of a design. Typically, team members used two hands partially or fully interlocked, and in up-turned position to illustrate how parts of a structural element are joined together while predicting their performance. For example, a designer in a meeting to evaluate structural decisions of a walkway, gestured with his two hand partially interlocked in up-turn position on 3D CAD rendering of the walkway to predict how the shell component of the walkway will fit to the head of the vertical structure saying,

"… if the base of the shell is tilted slightly, it will connect well with the head of the vertical structure, thus maintaining stability in the structure" (see Figure 4.31).

Figure 4.31. *A designer gestured with two hands cupped in up-turn direction on 3D CAD rendering of a walkway displayed on a SmartScreen during a design meeting to demonstrate how the shell and vertical column of the walkway will connect to maintain stability in the structure.*

4.5.4.3 Gestures in different information representations

Gesturing appeared to vary across different form of information in the meetings observed. The variations were observed on types and accomplishment of gestures with design information as well as engendered conversations and activities. The design team mostly gestured on information representations such as virtual reality (VR) models, 3D CAD rendering and 2D sketches while interacting with design information.

Gesturing with VR models seemed to be prevalent in the meetings observed within the wall display digital space. Basically, the team members employed pointing, touching and parallel indication gestures to reference, direct attention or support navigation as they performed a task. Most gestures on VR model were accomplished remotely, accompanied by verbal descriptions. On few cases, team members directly touched the wall display medium to interact with content of the VR model. These actions were observed to shape flow of interaction and ensuing conversations among the team members. For example, in one of the meeting sessions conducted to identify and resolve potential design issues in the VR model mediated meeting, team members employed touching and pointing gestures to direct attention and clarify issues around constructional arrangement of a brick wall (see Excerpt 1).

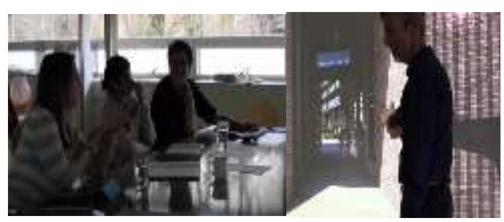
Episode 2 (E2), 21st of January 2018

Excerpt 1 [244: 092. 30-247:094.45]

B244: *((viewing and pointing to the model))* I think there is always a joint, those walls are going into the joint. On the balcony it is always difficult because the walls there are of different heights.

C245: *((Touching the VR model on wall display and viewing)).* Where is this? What I am asking is, whether or not there is always a junction there. Is that all is there? One brick thick and a junction.

Participant C directly touched content of design information displayed on the wall.



Participant C listens and provides clarification to ensuing conversations stimulated by his action.

A246: Yeah it will be nice suggestion.

D247: *((pointing to the model)).* Yeah because there is always a line there we might have tied that.

Excerpt 1 (E2) illustrates how the design team gestured via pointing and touching to interact with VR model on wall display medium during a meeting session. In this instance, the design team attempted to evaluate suggestion a of team member towards resolving constructional challenges of junction walls behind a door element. Participant ‘B’, in line 244 (Excerpt 1) pointed to section of the wall to reference and direct attention while providing explanation on prior suggestion. In seeking further clarification, Participant ‘C’ in line 245 (Excerpt 1) moves to the wall display medium and touched the brick wall with a query “Where is this? What I am asking is, whether or not there is always a brick junction there”. By touching the design element on the wall display, the participant reinforces and also simplifies description of the underlining concern. The query with the accompanied gesture appeared to have been accepted by other team members of which Participant ‘A’ in line 246 (Excerpt 1) remarks “Yeah, it will be nice suggestion”. While Participant ‘D’ supports the proposal, she supplements with further elaboration “Yeah, because there is always a line there we might have tied that”. In this instance, although Participant ‘C’ touched the wall display to direct attention and aid elaboration of his concern during evaluation of a proposed solution, the gesture with accompanied verbal descriptions aided understanding of the proposed idea and further stimulated conversations in the form of explanations to enrich the design decision in relation to construction of the intersection walls.

In contrast to VR model representations, gesturing with 3D CAD rendering appeared to be revealing in terms of type, accomplishment and engendered conversations during the meetings session. All of the types of gestures captured in the observations were witnessed while the team members interact with the 3D CAD rendering displayed on the SmartScreen. Besides, participants often gestured directly or near the displayed information. In most occasions, gesturing on 3D CAD renderings supported tasks such as describing, explaining, and evaluating design decisions. While gestural actions supported these communication tasks, it also stimulated emergence of activities such as generation of alternative solutions as well as sketching. An instance of this is shown in Excerpt 2 (E4).

Episode 4 (E4), 24th of March 2018

Excerpt 2 [124:045. 36-127:047.45]

A124: *((Pointing with forefinger on content of design information displayed on screen)).* This part forms the vertical structure, independent to the shell and main base of the walkway. However, it functions to provide support to the entire structure in this connection.

((Gesturing with the fore finger to specific portion of design information on SmartScreen display))

D125: It appears the stability of the independent structure supporting the form and the entire structure is a bit suspect judging from its arrangement and transitioning to the main component. I suggest the height and shape of the tripod be realigned properly to bring stability into the structure *((Moves and gestures on design information to clarify proposed suggestion)).*

((Pointing to design information on screen while explaining rationale of design proposal to the team)) members)).

A126: In that case how will v-column and the height be merged with shell and the canopy area.

D127: I mean it can be done this way *((moves to the activity area, picks a paper, and sketches proposed idea initially gestured to provide further clarity to the team members)).*

nds to explain ctural changes, in ndent component of

Excerpt 2 (E4) exemplifies how the team members gestured on 3D CAD rendering to support their tasks during a meeting session. In this fragment, the team members were attempting to evaluate design decisions on form and sizing of structural members in connection with stability of the walkway. Participant 'A' in line 124 (Excerpt 2), points with a fore finger to part of the walkway constituting the vertical structure to direct attention while describing, "This part forms the vertical structure, independent to the shell and main base of the walkway". While describing features of the structure, Participant 'A' further gestures and explains, "… it functions to provide support to the entire structure in this connection." [Line 124, Excerpt 2]. In this case, by interspersing gestures with description and explanation of the vertical structure, Participant ‘A’ attempts to provide more elaboration on specific content of the walkway under consideration thereby enhancing understanding among the team members. However, while Participant ‘A’ provides information on rationale underpinning design of the vertical structure, Participant ‘D’ in line 125 (Excerpt 2) appears to have issues with the decision by remarking “It appears the stability of the independent structure supporting the form and the entire structure is a bit suspect judging from its arrangement and transitioning to the main component”. Consequently, Participant ‘D’ proposes a suggestion “I suggest the height and shape of the tripod be realigned properly to bring stability into the structure”. In attempting to provide further clarity, Participant ‘D’ moves directly to the screen, points with fore finger to aspect of the vertical structure to reinforce his explanation. The suggestion to realign height and shape of the tripod appears to be unclear to Participant ‘A’, hence probes “In that case how will v-column and the height be merged with shell and the canopy area.” [Line 126, Excerpt 2]. In responding to the query, Participant ‘D’ in line 127 (Excerpt 2) moves to the activity area, produces a sketch of the idea on paper and gestured with two hands spread apart to explain performance of the proposed solution while other team members observe. By intermixing sketching, gesturing and explanations, Participant ‘D’ attempts to enhance understanding of the proposal in relation to design of the vertical column. This instance has shown how the team members supported their descriptive and explanative tasks with varying kinds of gestures while interacting with the 3D CAD rendering and the consequence of these actions on related activities such as sketching, and evaluation of proposed solutions during the meeting session.

4.5.4.4 How gestural action was accomplished in design meetings observed

The design team seemed to accomplish gestural actions through different methods, including remote gesturing and direct gesturing. Typically, the team members gestured remotely or directly on design information during the meeting session. Remote gesturing meant that team members reference design information at a distance, while in the case of direct gesturing, participants either touched displayed information via hand, pen or referenced from a close proximity. The observation reveals variation in gesture-related tasks across the different methods of gesturing employed.

Remote gesturing mainly appeared to be aligned with descriptive and explanative tasks in relation to design information. The team members often accompanied remote gestures with more verbal descriptions to either elaborate on design issues or identify specific areas of concern. For example, the lead architect in a design meeting to evaluate landscape architecture of a design project, pointed remotely on the landscape section of the VR model projected on the wall display and described nature of an issue identified in connection with the proposed landscape "So that part is the start of the big crack. So, this one colour and the other is gravel, and that is the difficult to start pave the ground. And as you can see, this gravel stretched along." In this case, the participant accompanies his remote gesturing action with descriptions on nature of the issue to provide more elaboration and enhance understanding of the concern associated with the landscape aspect of the VR model.

In contrast to remote gesturing, direct gesturing was seen to be associated with evaluating task. In most cases, team members interspersed direct gesturing with suggestions for modifications in existing decisions or predicting performance of proposed solutions to design queries. For example, a participant in a move to propose an alternative to sizing of railing members in a meeting to evaluate structural decisions of a walkway, walked to the SmartScreen display medium and pointed on railing component with a pen providing suggestions to address the anomaly as shown in Figure 4.32.

Figure 4.32. *A participant gesturing pointing directly on design information displayed on SmartScreen medium while providing suggestions to changes on sizes of railing members of a walkway in a design meeting session.*

4.5.4.5 Interplay between gestures and other actions

Interplay of gestures with other types of interaction, both verbal and non-verbal were noticed during the design meeting. Participants fluidly interspersed gestures with viewing and navigation actions while attempting to describe and explain design rationales as well as evaluating design information (see Section 4. 6.4.4).

Summary of gesturing with design information in design meetings observed

- The design team employed gestural actions to accomplish variety of goals, including directing and capturing attention of team members, relate design elements, represent information as well as describe and explain design elements while discussing issues about the design.
- Gesturing is the richest non-verbal interaction emerged in the design meeting as more participants used varying forms of gestures to engage with the design information which tended to attract and incite dynamics in the exchanges of the team members.
- Gesturing at design information via large touch-sensitive display interface appears to be richer as many participants adequately took turns to point at design information, spread hands to indicate shape, size or movement of design elements and functions onscreen compared to the non-interactive large display medium.
- The design team employed different forms of gestures with unique appearance and use, including pointing, two-finger indication, parallel indication and interlocked indication to interact with design information.
- Gesturing in VR models seemed to be prevalent since participants employed pointing, touching and parallel indication gestures to reference, direct attention or support navigation task. However, accomplished remotely with extensive verbal descriptions.
- Gesturing was more revealing in the 3D CAD rendering, SmartScreen display medium in terms of type, accomplishment and engendered tasks during the meeting session as the team utilised all types of gestures while interacting with the design information onscreen.
- The design team accomplished gesturing actions through different methods, including direct gesturing and remote gesturing.
- There were variations in gesturing-related tasks in relation to different methods employed, since remote gesturing incited descriptive and explanative tasks while direct gesturing associated with evaluative task.
- Gesturing interplayed with other types of verbal and non-verbal actions as

Chapter 5 : Discussion

5.1 Introduction

The preceding chapter analysed the communication instances of the design team, range of media employed and the team's interactions with media in the digital space during in-house design meeting sessions. The aim of this study was to explore nature of verbal communications and non-verbal interactions of team members and how they are supported by media used in the digital space during architectural design meetings.

In general, the findings revealed that the design team employ different communication instances (i.e., descriptive, explanative, evaluative, and exchanging) and non-verbal actions (viewing, navigating, gesturing, annotating and authoring) in relation to the media (information representation and display medium) to communicate the design and perform specific activities in the meeting encounter. In addition, the results showed that varying capabilities (i.e. walkthrough, manipulation, annotation and mark-up, interactivity, realism, spatial relations, geometry) of the media are richly utilised to mediate the verbal conversations and actions of the team, and that emergence of these behaviours tend to vary in the ways in which they interact with the media.

This chapter is divided into three sections that discuss the range of media employed to support interactions among the team members, communications instances and non-verbal interactions in relation to the media during design meetings. The final section provides a summary of the issues discussed.

5.2 Media used to support interactions in the design team

The design team supported their knowledgeable actions with varying range of media including both the information representation and the display medium. This section discusses major findings emanated from the analysis of the video data in relation to use of digital media (information representation and display medium) during the meeting session.

5.2.1 Type of information display medium used in design meetings

The results revealed that the design team used a range of mediums, including both fixed-type displays (e.g. multi-projector screen, wall display and SmartScreen display) and personal mobile devices (e.g. tablets or smartphones) to support their visualisation of design information during the meeting session. This suggests that the design teams consider the digital space as a fluid environment where any available display mediums, irrespective of ownership or setup can be used to aid display of design information during the meeting session. The reliance on both fixed and personal devices to support information visualisation during the meeting session could be attributed to a number of reasons. Firstly, limitations may exist in the formal setup of the digital space since participants can introduce new information which has to be shared to aid conversations about the design. Since formal visualisation setup of the digital space might not have accounted for the transfer of private information into shared displays, the use of mobile devices to additional information becomes inevitable in the team's workflow.

Secondly, mobile computing has become ubiquitous or democratic, hence there is a tendency for participants to work on their own mobile devices when introducing new information. Besides, the influx of mobile devices has changed people's preferences in ways of accessing and sharing information during meeting sessions as observed by (Fard et al., 2006). Thirdly, enhancement in functionalities of mobile devices, for example, interactivity of the display interface has generally simplified how participants share and access information. This finding corroborates prior observations by Fard et al. (2006) and Whyte et al. (2016), that mobile computing technology (tablet, smartphones) have become useful in supporting display of information, arguing that the participants' preference in sharing information on smaller displays compared to larger displays appears to be gaining root in design meetings. This implies that for effective utilisation of personal mobile devices to augment shared displays, provision needs to be made to ensure that personal and public devices are adequately mediated to aid smooth transfer of private information. As noticed by Kister et al. (2017) successful combination of personal mobile devices and shared displays is useful to increase access and interaction of information during the meeting session.

Unlike prior investigations on use of personal devices (e.g. Fard et al., 2006; Fard, 2006), the current study noticed variations in use of personal devices (tablet, smartphones) during the meeting session. The design team utilised mobile devices either as principal display medium or supplementary to a shared display. Generally, when new information was being introduced, the personal devices were used to augment the information on fixed displays. The reliance on personal devices as sole display medium could be attributed to enhanced functionalities of the mobile device to support access and viewing of computer aided design (CAD) drawings and other forms of information. Whyte et al. (2016) report that improvement in both hardware and software capabilities of mobile devices has made usage of CAD and other 3D visualisation applications possible, although previously restricted to desktop computers. Accordingly, since participants in the design team can leverage on enhancements in personal devices to view and access information via their personal mobile devices, design information needs to be developed in such a way as to allow for easy display and navigation during the meeting session. Besides, differences exist in capabilities of mobile devices to support information visualisation, hence simplifying information representations is necessary to compensate device variations on displaying shared information during the meeting session (Ahsan et al., 2007). By this, the design team can access and respond to the current information simultaneously thereby enriching deliberations about the evolving design.

The analysis further revealed that use of personal devices during the meeting session tends to structure members' participation and flow of interaction. While use of mobile devices provides opportunities for participants to access and view new information during the meeting session, this does not come without a challenge to the flow of conversation among the team members. Because of small screen size of mobile displays, its use in viewing information often demand that participants pass around the mobile device for new information to be shared among the team members. Consequently, tendency for halting current conversations about the design for adequate familiarisation with the new information is likely to occur during the meeting session. This finding confirms Fard et al. (2006) observation that deploying personal devices to support sharing of new information often tends to disrupt flow of discussions among team members. Therefore, while members are encouraged to share private information publicly via personal mobile devices, the digital space should be equipped with mechanisms to ensure easy transfer of new information, thus enhancing meaningful conversations about the design.

This sub-section has discussed types of display mediums utilised to support participants' interaction with design information during the meeting session. The discussion argued that design team employed both permanent and mobile displays in different configurations, hence structuring participation and conversations among the team members. The next sub-section is devoted to discussing use of information representations to mediate actions and activities among the team members during the meeting session.

5.2.2 Mode of representations employed to communicate design content

The findings revealed that the design team used varying forms of information representations including VR models, 3D CAD renderings, 2D CAD views, multimedia data and 2D paper drawings to mediate their actions during the meeting session. However, variations existed in mode of use of information representations in the team's workflows. The analysis revealed two main modes of use of design information, including principal information and supplementary information. Generally, principal information, which included VR models and 3D CAD renderings were used to drive interactions (i.e. verbal and non-verbal) throughout the meeting session. By contrast, supplementary information comprising 2D CAD views, multimedia data and 2D paper sketches emerged either to support detailed discussions or address limitations in principal information representations.

The results corroborate prior findings on use of information representation in design meetings (e.g. Liston et al., 2001; Liu, 2016; Mehrbod et al., 2019; Tory et al., 2008), that use of mixed media has become paramount in attempting to meet informational needs of participants during design meetings since no single representation possess all essential characteristics about the design. For instance, Liu (2016) concluded that VR models and traditional drawing media are good for different tasks and hence their capabilities complement each other and not to replace one another. This suggests that switching back and forth between different representations in the interaction process is necessary to compensate for deficiencies present in individual representations. Accordingly, techniques employed to display design information during the meeting session need to account for transitions between various representations for uninterrupted flow of conversations among the team members, since as maintained by Mehrbod et al. (2019) challenges often emanate when transitioning between different representations of information.

The findings further suggested that the design team used both public and private information to mediate their task during the meeting session. Basically, use of private information occurred during the team's deliberations on principal information and tended to shape participation and flow of conversations among the team members. Besides, use of private information were mainly mediated by mobile devices during the meeting session. Conversely, public information existed prior to commencement of the meeting session and its use was mainly enabled by centralised displays. This suggests that information needs of participants in the design team are generally unpredictable, hence difficult to satisfy prior to the meeting section. The variations in information utilisation in terms of ownership could be attributed to the fact that information representations are often limited in amount of content, thus inadequate to define the various attributes defining the design. Besides, participants may provide additional information during the meeting to respond to current discourse about the design. Since circumstances of its emergence is situated within the context of conversations around the design, its provision cannot be made a-priori.

This finding confirms Fard et al. (2006) observation that participants in design teams often introduce private information during the meeting session to augment existing information while attempting to develop the design. This implies that in assembling relevant information to support design deliberations, provision needs to be made to ensure that private information is adequately shared to yield the needed response.

Unlike prior observations on use of information representations in design meetings (e.g. (Liston et al., 2001; Liu, 2016; Mehrbod et al., 2019; Tory et al., 2008), the current study reports on circumstances accounting for use of design information. The findings indicated that circumstances including supporting the team's communicative task, overcoming limitations in prior representations, and providing alternatives to design decisions necessitate use of information during the meeting session. Generally, circumstances leading to use of specific information representations during the meeting session often tend to be unpredictable due the situated nature of actions in team meetings as alluded by (Jordan and Henderson, 1995) as well as (Orlikowski, 2000). Hence, flexibility needs to be introduced while assembling various information representations to ensure adequate coverage of participants' information needs during the meeting session.

Overall, the participants rely on varying forms of information representations under different modes of usage and ownership, hence adequate facilities be provided to ensure transition between various representations are smooth, and that private information are well transferred to shared displays for meaningful conversations about the evolving design. The next section discusses the communicative tasks supported by design representations during the meeting session.

5.3 Communication instances in the design team

5.3.1 Describing design information

The analysis revealed that the design team occasionally engaged in descriptive communicative task to orientate and provide overview about features of the design. However, according to the results, variation existed in emergence of descriptive conversations during the interaction process. Generally, participants described design elements either at the commencement of meeting sessions, start of new topic about the design or at the introduction of new information. The occasional emergence of descriptive task indicates that participants had ample understanding of design features hence needed to concentrate more on tasks interrogating design choices. This finding appears to contradict prior observations on communicative tasks in team meetings (e.g. (Fard, 2006; Liston, 2009; Liu, 2016), that descriptive communication instances dominate conversations about the design during meeting sessions as it helps participants to develop common understanding of the design.

The discrepancy in emergence of descriptive conversations could be attributed to several reasons, including differences in nature of the team meeting since meetings in prior studies tended to be interorganisational and multidisciplinary in nature compared to in-house nature of the current study. Another reason may be that team members in the current study were already familiar with current content of the design, hence could afford concentrating on task critical to developing the existing design. Besides, since members of in-house design teams are generally design professionals, they are likely to have expert knowledge about demands of the task thus better positioned to interrogate critical relationships of the design as asserted by Liston et al. (2001). Nature and requirements of the task could also contribute to low descriptive conversations observed in the current study since participants needed to satisfy themselves more about decisions on function, safety, ergonomics, and sustainability issues about the design. The implication is that understanding nature and composition of the design team is critical to ensure that only essential support towards facilitating descriptive activities are provided when planning the design meeting. Hence ensuring that areas of utmost importance towards developing the evolving design are adequately resourced during the meeting session.

Furthermore, the results showed that participants richly supported their descriptive task with varying content of information and other non-verbal interactions including viewing and gesturing. Generally, the design team referenced and directed attention to aspect of the design information via gesturing to describe design features. This indicates that the design team considered availability of informational resources critical to accomplishing their descriptive task during the meeting session. The reliance on content of design representations towards providing general understanding about the design could be attributed to richness and ease of use of the information representation as well as the desire to simplify descriptions about design characteristics. This finding aligns with earlier observations by Liston et al. (2001) and Liston (2009) that participants richly utilised information resources to aid description of design features during the meeting session. Accordingly, enough representations in varying levels of detail needs to be assembled while preparing for design meetings to ensure that descriptions about design attributes are clearly provided.

This sub-section has discussed that emergence of descriptive task are occasional and tended to vary in the team's workflows, however, richly supported by available informational resources. The next section discusses how the design team shared design information for meaningful conversations about the design.

5.3.2 Exchanging of design information:

The findings revealed that the design team occasionally shared different forms of additional information, including 2D digital photos and traditional paper and pen sketches to support their discussions. Generally, sharing of new information occurred when participants needed to provide further clarity about existing or proposed solutions while deliberating on design decisions. This indicates that information provided prior to commencement of the meeting are considered inadequate to meaningfully stimulate discussions about the evolving design. Because information representations are generally limited in content, possibility for generating and sharing additional information while interaction unfolds is likely to emerge. Besides, since information needs of participants are in most cases context dependent, amount of information assembled prior to the meeting might not adequately address their needs, hence likelihood of introducing new materials to support their deliberations. This finding confirms earlier observation by Liston (2009) and Fard (2006) that participants in team meetings occasionally share information while attempting to clarify issues about the design. Consequently, since introduction of new information during the meeting session becomes inevitable, adequate provision needs to be made when planning the meeting to ensure that participants easily access the shared information without any hitches to the interaction process.

5.3.3 Explaining design information

The findings revealed that the design team engaged in explanative task to clarify design decisions during the meeting session. Variations existed in emergence of explanative task during the meeting session. Generally, participants provided explanations on design issues when justifying existing design choices and attempting to provide suggestions towards refining the design. This indicates that emergence of explanative task may depend on the context within which discussions about the design are held. The variation in occurrence of explanative task could be attributed to different strategies employed by participants to reinforce understanding while contributing to enrich discussions about aspect of the design. Besides, limitations often exist in information employed to aid discussions about the evolving design in terms of content, hence possibility for the introduction of new information to enhance understanding of suggested idea is likely to occur during the meeting session.

This finding confirms earlier observations on communicative task in design meetings (e.g. (Alsafouri and Ayer, 2019; Fard et al., 2006; Liston et al., 2001) that participants engage in explanations to ensure understanding of design choices during the meeting session. In addition to prior findings, the current study noticed that variations exist in emergence of explanative task due to its context dependent nature. The implication is that planners of design meetings need to be aware of the context within which discussions about the evolving design are held to provide appropriate support for effective explanation of design choices during the meeting session.

The results revealed that the design team extensively supported their explanative task with both existing and new information including paper and pen sketches and multimedia data during the meeting session. Since successful explanation generally thrives on availability of important information within the context of the proposed suggestion, and that limitations often exist in amount of information revealed by information representations, tendency of using both existing and new information to aid explanation of design issues is likely to occur during the meeting session (Tory, 2004; Tory et al., 2008). This finding confirms previous observations on supporting communicative task in team meetings (Fard et al., 2006; Fard, 2006), that participants combine both shared and personal information to enable access to large array information while explaining design issues. Accordingly, efforts need to be made to ensure that existing and new information lend themselves well to support clarification of design decisions during the meeting session.

Furthermore, unlike prior investigations into interactions in design meetings (e.g. (Alsafouri and Ayer, 2019; Liston et al., 2001; Liston, 2009), the current study indicated that explanative task tended to vary across different information representations and display medium in terms of richness. According to the results, participants engaged in extensive explanative task in the 3D CAD rendering SmartScreen mediated meeting compared to the other mediated meetings (i.e., VR model and mobile devices). Since participants often rely on information about the design to aid clarification of suggested ideas, how the design information is represented and displayed generally has the tendency to influence amount of information available to participants in the design team. Accordingly, information critical to facilitate explanation of design ideas in the 3D CAD rendering SmartScreen mediated meeting may differ, hence contributing to variations in emergence of explanative task. Another reason could be attributed to level of development of the design since differences exist in phase of development of the evolving design. For instance, the design task mediated by the 3D CAD rendering SmartScreen display was at its conceptual stage compared to the others which were in their design development stage (Section 4. 3. 3). Hence, since conceptual design often attract more suggestions to refine design decisions, demand for extensive explanations to enhance understanding of proposed ideas is likely to be higher compared to the other levels of design development. Therefore, media assembled to aid clarification of design ideas needs to be aligned to the stage of development of the evolving design thereby responding to specific demands imposed by context of the current design.

This section has discussed emergence of explanative task and how it is mediated during the meeting session. The discussion argued that emergence of communication task varies in different situations and mediated environments, hence context of its emergence needs to be understood while planning meetings to tailor support specific to the current need of the explanative task. The subsequent section discusses main findings on evaluation of design information during the meeting session.

5.3.4 Evaluating design information

The findings revealed that evaluating design information dominated the team's verbal conversations around the design. This suggests that the design team considered evaluation as a fundamental communication act in their quest to develop the evolving design. This finding appears to differ from prior observations on participants' conversations in team meetings (Liston et al., 2000; Liston et al., 2001; Liston, 2009; Liu, 2016; Olson et al., 1992), that descriptive type of communication forms the bulk of participants' verbal interactions during team meetings since this provides opportunity for members to obtain common understanding of the design. The discrepancy emanated in the current study could be attributed to several reasons, including differences in representation and display of design information; composition of the design team which happens to be design professionals working within the firm (in-house design team); familiarity of team members with the design project as participants demonstrated previous knowledge about the design. Accordingly, for participants to richly engage in conversations towards evaluating decisions about the design, mode of representation and presentation of the design needs to be given priority since this informs how well the information is understood and utilised. Besides, consideration of participants' expertise on the current design task as well as their knowledge of ongoing design project are essential to ensure that details and choices of the design are adequately interrogated during the meeting session.

The results indicated variations in emergence of evaluation task around different representations of design information. The design team engaged extensively in evaluation task in the 3D CAD rendering SmartScreen supported meeting compared to the VR model mediated meeting. This means that issues pertaining to compliance of design requirements and standards underpinning the design seemed to be paramount in the team's conversations around the design. The emergence of rich evaluation task observed in the 3D CAD rendering may be ascribed to nature of the information representation as well as the display medium. Generally, the 3D CAD rendering of the design was limited in design content compared to the VR model. Hence more design concerns regarding function, ergonomics, safety, construction and operation are likely to be topical in the 3D CAD rendering of the design. Again, since requirement of the task necessitated availability of data-rich information to inform decisions, any shortfall in characteristics of the design might attract more concerns from the participants thereby fuelling thorough scrutiny of the design. Another possible reason accounting for richer engagement in evaluation conversations around the 3D CAD rendering in comparison of the VR model could be aligned to differences in stages of the design development. Since, 3 CAD rendering of the design was in its conceptual stage, attempt to evaluate existing and alternative solutions may be higher compared to the VR model representation which was in its design development stage.

This finding confirms initial analysis of the study (Ofori-Darko et al., 2018) as well as findings by Alsafouri and Ayer (2019), that evaluating design information vary across different representations since several issues, including content of the design, representation and presentation of the information as well as stage of design development tend to inform emergence of evaluation around the design. While enriching the content, interactivity and display of design information is considered in prior studies (e.g. (Liston et al., 2000; Maldovan and Messner, 2006) as key to enhancing participants' interrogation of design attributes, equally important are the requirements and expectations of the design as well as phase of design development as these form the context of the design. Hence, ample consideration needs to be given to these contextual issues while attempting to stimulate conversations towards evaluating the design during the meeting session.

Furthermore, the findings revealed that the design team richly utilised facilities of the display medium, specifically, navigation functionalities (virtual walkthrough/flythrough) and touch-sensitive interface of the SmartScreen to support their evaluation task during the meeting session. Since evaluation of design information requires accessing and establishing critical relationships of design information, reliance on facilities enabling adequate access and manipulation of design content becomes critical in evaluating design information. As argued in prior studies (Liston et al., 2000; Maldovan and Messner, 2006) opportunity to access relevant aspects of design information is key to adequate evaluation of the design since success of this hinges on availability of relevant details of the design. Accordingly, quest to ensure rigorous scrutiny and use of design information during the meeting session demands provision of ample opportunity for participants to richly engage with varying details of the design.

However, while the design team extensively mediated their evaluation task with navigation and interactive interfaces of the medium, the results showed that accomplishment of evaluation task varied across different display medium. The design team incorporated more of virtual walkthrough/flythrough actions while interrogating elements and proposed solutions of the design in meetings supported by the multi-projector and wall display screens. Conversely, participants in the SmartScreen enabled design meeting interspersed their evaluation task with on-screen view set-up manipulations of the design via hand touch as this provided them opportunity to gain better perspectives of the design and make informed comparisons during the meeting session. The variations could be attributed to differences in navigation facilities afforded by the display medium and the visualisation application. For instance, although the wall display and multi-projector interfaces did not support direct manipulations of design information on screen, participants richly utilised virtual walkthrough/flythrough functionalities of the application software (i.e. Enscape plug-in for Revit) to mediate their evaluation task. This seems to suggest that in attempting to facilitate adequate evaluation of design content, both the application software and the interface of the display medium need to be considered since each has the tendency to structure the way participants scrutinise design decisions as observed by (Liston et al., 2001).

This section has discussed issues pertaining to emergence of evaluation of design information in the meetings observed and has argued that evaluation instance of communication is a situated action which draws on the context of the media assemblage (information representation and display medium) and background of the team in relation to the design task, hence distinct in different digital spaces. The proceeding section discusses the various non-verbal actions with which the design team interacted with the design content while communicating to understand and develop the design.

5.4 Interacting with the media

The study observes variations in the way participants interacted with the display medium and information content. The study also noticed variations in the way conversations unfolded around different media. This section discusses key findings on non-verbal actions, including viewing, navigating, gesturing, authoring (sketching) and annotating design information

5.4.1 Viewing design information

Viewing was identified as the most dominant way with which participants in the design team interacted with design information. This suggests that the design team attached importance to familiarising with content of the design prior to its usage. This finding corroborates earlier observations (e.g. (Addor and Santos, 2014; Liston et al., 2001; Liu, 2016; Ofori-Darko et al., 2018; Tory et al., 2008), that viewing design information permeates participants' interactions with the design. Accordingly, ample opportunity for enriching viewing action needs to be provided to ensure team members are adequately familiar with content of the design.

The findings revealed that the design team viewed information in three different ways including group viewing, sub-group viewing and individual viewing during the meeting session. According to the results, variations in viewing mainly emerged at the introduction of new information in different presentation medium. Information available at the commencement of a task was viewed publicly by the design team, whereas new information introduced in the course of the meeting was watched, either in sub-groups or individual bases.

This suggests that the design team appears to introduce dynamics in their approach to looking at displayed information during the meeting session. The differences in approach to viewing design information could be attributed to nature of the display medium as the medium generally tend to differ in many ways, including size and ownership. For instance, large display screens (e.g. wall display) have large viewing area which enable information to be brought in focus of the entire team thereby facilitating group viewing. Conversely, small displays such as tablets and smartphones have limited viewing area hence unable to allow simultaneous access to displayed information. Since not all participants may have immediate opportunity to view the current information, tendency of viewing the information in batches may be higher in the small display medium.

Another possible reason could be attributed to ownership of the display medium since participants viewed information both on public displays and personal devices. Generally, personal devices used to support information display are smaller in size and mobile in nature compared to the public display (e.g. multi-projector screen), thus possibility of looking at information displayed on mobile devices in turns or sub-group may to be higher during the meeting session. Besides, nature and relevance of the new information could change the way participants view design information. Generally, team members tend to be curious when new information considered critical to enrich discussions are introduced or generated during the meeting session. For example, creation of paper and pen sketches during the meeting session often attracted attention of a section of participants thereby resulting in sub-group viewing (see section 4.4.1).

This finding aligns with earlier observations (e.g. (Fard et al., 2006; Liston, 2009), that participants in team meetings often view information together as a group, but occasionally do so in sub-groups or individuals when new information are introduced. However, in addition to this finding, the current study noticed that individual viewing could also serve as a primary viewing approach as team members per arrangement of the digital space often use their personal mobile devices to view shared information during the meeting session. Consequently, since viewing of design information could take different forms per assemblage of media support and nature of information utilised, efforts need to be made while planning for meetings to ensure that introduction of new information via personal devices are accessible on shared displays for meaningful interrogation. Another implication is that shared information needs to be prepared in such a way as to ensure smooth viewing on individual's mobile devices (i.e. tablets, smartphones) since simultaneous access to design information has the tendency to enrich conversations around the design during the meeting encounter.

Variations in approach to viewing design information tended to shape flow of interaction and participants' involvement in conversations around the design. According to the findings, group viewing which was associated with large display screens (e.g. wall display, SmartScreen displays), generally preceded discussions on design issues and mainly happened a distance from the screen. The large screen size might have informed the way participants looked at design information from a distance since members had opportunity to observe current information together, hence converging their attention on the issue at hand. Unlike group viewing, sub-group and individual viewing mainly happened at the introduction of new information and accomplished near to the displayed information. Since sub-group and individual viewing generally occurred around mobile devices and traditional paper media, the smaller nature of the display size coupled with its portability necessitated that participants either crowded around or give a close look at displayed information to familiarise with its content.

This result is consistent with earlier assertion by Fard et al. (2006) and Fard (2006), that flow of interaction in design meetings tend to be disrupted upon introduction of personal displays such as tablet and laptops since provision to mediate use of personal and shared displays are not adequately provided during the meeting session. Hence, while attempting to utilise different display medium to aid viewing of design information, how they are mediated to attain a common platform is critical to ensure uninterrupted conversations about the design during the meeting session.

The observation showed that the design team viewed a wide range of information during the meeting session, nonetheless variation existed in how viewing was done across the representations. The team viewed design information considered principal to their workflows (e.g. VR models and 3D CAD renderings) first, before switching to view supplementary information critical to providing details about the design (e.g. 2D CAD elevation views). However, introduction of new information in the course of the meeting session (e.g. sketches) were given immediate viewing. The variations in viewing design information could be attributed to differences in content provided by the primary information representation compared to the supplementary ones. For instance, VR model as a main information representation contain both exterior and interior content of the design, hence viewing its content at the early stage is likely to provide general knowledge about the design. By first obtaining insight about overview of the design, participants can direct attention to the detail information provided as supplementary material.

This result partly corroborates earlier observations on viewing of design information (e.g. Liston et al., 2001; Liston, 2009; Liu, 2016; Mehrbod et al., 2019; Tory et al., 2008), that participants in team meetings switch between different representations to view design information. In addition, the current study noticed a trend in which participants view information in different representations, indicating that representations with general information and higher level of detail precede information with specific aspect of detail about the design. Accordingly, while participants in the design team need to be provided with opportunity to view information in different representations seamlessly, knowledge on moment of their use is critical to inform how best each representation is appropriately displayed during planning of design meetings. As maintained by Liston et al. (2001), each information representation has distinct data structure which needs to be visualised to enable team members adequately interact with essential relationships of design features thereby ensuring adequate use of design information during the meeting session.

Furthermore, the findings showed that the design team viewed information on varying display medium including multi-projector screens, wall display, SmartScreen, mobile devices (tablet and smartphone) and traditional 2D paper. Information on wall and multi-projector displays were generally viewed simultaneously by the entire team while mobile displays and paper media were viewed in sub-groups or individual bases. In the case of SmartScreen display, the results indicated that all the three forms of viewing (i.e., group, sub-group, and individual) as previously discussed occurred during the meeting session. The discrepancies in viewing could be attributed to differences in display size, application software as well as interactivity of the display interface. For instance, the wall display medium had facilities such as large viewing surface, view setup and navigation functionalities supported by the Enscape plug-in Revit application. These functionalities provided opportunity for relevant information to be brought within the view of participants at a distance without necessarily crowding around the display for adequate viewing. By contrast, while the SmartScreen had a sizeable area to support group viewing, opportunity for view adjustment was enhanced via the touch-sensitive of the interface. Accordingly, tendency for a section of the participants or individuals gathering around the SmartScreen to obtain a better view of information is likely to occur during the meeting session.

This finding confirms earlier observations on capabilities of media to support information visualisation (Fard et al., 2006; Ofori-Darko et al., 2018), that participants utilise different display medium, with varying capabilities to view design information during the meeting session. Since different facilities of the medium including display size, interface interactivity as well as view manipulation tools of the software application inform different viewing of design information, effort needs to be made to ensure that relevant facilities of the display medium are adequately utilised to enrich information visualisation during the meeting session.

The results revealed that the design team viewed design information one at a time regardless of size or number of the display screen during the meeting session. There was no simultaneous viewing of multiple information on screen contrary to earlier observations (e.g. (Liston et al., 2001; Tory, 2004), where variety of information were viewed simultaneously on screen during team meetings. Participants preferred spanning single information across multiple screens rather than bringing multiple data across presentation medium. The decision to view single information at a time could be attributed to the purpose with which a representation of information is used since differences exist in the way participants use information during a meeting session. For instance, the design team may use information representation as a build

-up on preceding information or to relate different aspects of information while discussing issues about the design. In situations where purpose of use of different aspect of information is additive rather than comparison, likelihood of looking at information one at a time will be greater irrespective of configuration of the display medium.

This finding aligns with Tory (2004) and Mehrbod et al. (2019) (Tory, 2004) observations that participants in team meetings preferred working on single data-rich information at a time. Mehrbod et al. (2019) argued that participants switched to view additional information for further insight rather than tiling multiple dataset on display when additional information was needed. Hence, since demand of a design task generally underpins information needs of participants, which in effect informs how multiple set of information are visualised during meeting sessions, knowledge of social practice of the team within the digital space is critical to enhance understanding of how a display medium is utilised to support information visualisation. Insight into the team's workflows will ensure that planners of design meetings assemble display mediums appropriate to the task and information needs of the participants. As maintained by Orlikowski (2000), actual use of technological assemblage to support group task becomes manifests through its situated use.

This sub-section has discussed viewing interaction across different information representations and display medium during the meeting session in relation to prior findings, arguing that while viewing is a predominant interaction with which participants familiarise with design information, variation exists in its emergence and accomplishment across different representations and display medium. The proceeding section discusses major findings of navigation interaction emerged out of the analysis of the video data.

5.4.2 Navigating design information

Navigation was found to be an important non-verbal act with which the design team interacted with varying representations of design information during the meeting session. The findings revealed that navigation supported variety of the team's goals, including searching and relating information, describing and explaining features and rationale of design as well as evaluating design choices. Again, the data indicated that navigation enabled the team to query varying amount of design information and apply annotation on specific portions of the generated 2D digital photos during the meeting session. While availability of data-rich information about the exiting design may be helpful to support the team's activities during the meeting session, equally important is the means employed to access varying details of the design. Hence, navigation interaction considered a vehicle to the constituents of the design information in the team's workflow. This finding confirms earlier observations on navigating design information in teams (e.g. (Jul and Furnas, 1997; Mehrbod et al., 2019; Tory et al., 2008), that navigating digital information is a key way with which participants in the design team obtain knowledge about the design and access its varying details. Consequently, ample opportunities required for navigation to thrive, in terms of user-friendly navigation tools and input controls as well as upscaling of the navigator's skills, need to be provided to ensure that benefits enshrined in navigation interaction in relation to design information are realised during the meeting session. As acknowledged by Jul and Furnas (1997), successful navigation of digital information relies on availability of the essential components of navigation interaction including the navigator, form of information and the design content.

According to the results, the design team employed a variety of techniques, including walkthrough/flythrough, view set-up (zoom, rotate, orbit/pan) to navigate design information. Nonetheless, navigation techniques were found to vary across different information representations and display medium. Besides, each navigation technique shaped differently the way team members interacted with the information content. For example, the walkthrough / flythrough technique which was aligned to the VR model generally enabled the team to relate and engage with specific details of the information as well as explore overview of the design. By contrast, the view set-up technique, where the design team attempted to change size, position or current view of the design information permeated in all the media deployed to support representation and display of information. The variations could be attributed to the fact that navigation is generally informed by information needs of the team, hence availability of navigation tools as well as input controls often inform nature and exhibition of techniques required to accomplish the task. Again, since the task of navigating digital information often involves extensive manoeuvring to locate the desired content, expertise of the navigator becomes critical in such situations. Hence variations in navigation skills of participants may influence kind of techniques employed in accessing information during the meeting session. As maintained (e.g., Burigat and Chittaro, 2007; Jul and Furnas, 1997), the relevance of navigation functionalities afforded by a medium becomes manifest when users, regardless of experience, easily utilise the tools to access content of the information. Similarly, structure of the information representation in relation to nature and level of detail may contribute to differences in navigation techniques. For instance, in the VR model, both exterior and interior features of the design are revealed as well as the internal spaces, hence techniques employed to access them might differ compared to the 3D CAD rendering, where information content was typically limited to the 3D geometry and the visual characteristics of the design.

This findings appear to be similar to prior studies on accomplishing navigation task in design meeting sessions (e.g. (Mehrbod et al., 2019; Tory et al., 2008), who noted that participants in the design team use varying techniques to peruse varying content of design information, explaining that details of information representation informs nature of encounter with which the design team establishes with the design information. Besides, choice and usage of specific navigation techniques aligns in some cases to the skills and experience of the navigator during the meeting session. Accordingly, assembling of applications and tools to aid navigation needs to be aligned to content of the design as well as competencies of the navigator in manoeuvring the information space since they serve as necessary conditions for appropriate techniques to be utilised while navigating the design information.

Navigation interaction is seen as a situated task, taking its meaning from the social, material and the environmental context of the media (Alsafouri and Ayer, 2019; Jul and Furnas, 1997). This indicates that emergence of navigation interaction is dynamic in different material and social environments. The findings revealed that emergence of navigation interaction is distinct in different information representations and display medium. Navigating VR models was more compelling compared to other types of representations in terms of execution techniques, amount and detail of information accessed. The findings revealed that all the navigation techniques, as discussed in the preceding paragraph, were noticed in VR model supported design meetings. By this, the design team had opportunity to assemble relevant amount of information needed to support their discussions about aspects of the design. The richness in navigation interaction with the VR model could be attributed to several reasons, including the walkthrough/flythrough functionalities afforded by the Enscape plug-in for Revit application, availability and usability of the navigation tools as well as the display medium and expertise of the navigator. Besides, the goal of the design meeting and phase of the design in terms of design development, might have accounted for extensive navigation associated with the VR model. Since participants had responsibility of familiarising themselves with both the interior and exterior features of the design as well as identifying and resolving issues related to the design, the possibility of extensive navigation was likely to occur during the meeting session. Contrary to navigation in VR models, the results revealed minimal navigation with 3D CAD rendering visualised in the SmartScreen display medium. The nature of the task and phase of the design may have accounted for this development. For instance, the 3D CAD rendering representation of the walkway design was in its conceptual stage, hence more attention may have been devoted for thorough scrutiny of design choices. Another reason could be aligned to nature of the supporting software application and non-available navigation functionalities required to facilitate adequate perusal of the information content, since the PowerPoint (PP) application was limited in tools supporting navigation. For example, walkthrough/flythrough functionalities. Moreover, the form with which information was represented might have led to the minimal navigation, because 3D CAD rendering in nature is static, hence limited in opportunities to access content of the design.

In the case of 3D CAD views (parallel projections) as well as 2D CAD elevations, navigation interaction occurred mainly as follow-up to prior deliberations in relation to the VR model. The design team in the VR model mediated meeting used 3D CAD views and the 2D CAD elevations mainly as secondary information representations, hence navigated in cases where there was a need for specific details of the VR model. Besides, the practice whereby the design team engaged, first with the primary information representation (VR model) for general understanding of the design before descending to more specific details, in terms of constructability might have contributed to minimal navigation with the CAD views (2D/3D). Suggesting that how the design team choose to do their work is critical to understanding how well assemblage of design information is utilised, accordingly needs to be considered in the planning of navigation interaction during the design meeting.

The findings align with prior observation by Tory (2004) in their characterisation of participants' interactions with information representations during design coordination meetings that emergence of navigation interaction varied across different representations of design information. For instance, Tory (2004) eluded that since each representation is developed to reveal specific content about the design, quest to access details of the design becomes tied up to amount of information contained in the representational media. While findings of the current study confirm this assertion, other reasons including social practice of the team, availability and usability of navigational functionalities of the display medium, skills of the navigator as well as phase of the design development tend to inform extent of navigation interaction performed in the information representation. Hence, these issues need to be considered in attempting to enhance the ways with which participants in the design team access and interrogate content of design information during the meeting session.

According to the results, approach to accomplishing navigation interaction varied across different representations and display media during the meeting sessions. The design team accomplished navigation task as a collaborative activity in the VR model mediated meeting. The results revealed that participants worked together in the VR model supported meeting by providing varying inputs in the form of technical skills and verbal suggestions via keyboard and mouse input controls to accomplish the navigation task. In contrast, navigation in 3D CAD rendering SmartScreen display supported meeting was accomplished in solo through the mouse and keyboard input controls. The navigator (meeting facilitator) generally performed navigation task alone while leading discussions around the design information. In the case of mobile device (i.e. smartphone and tablet) supported interactions, the findings revealed that the design team accomplished navigation in turns via hand input and reliance on the touch-sensitive interface of the display screen. The smaller screen size of the mobile device might have accounted for the participants performing navigation interaction in turns displayed during the meeting session.

The variations in navigation approach may be attributed to several reasons. Firstly, goals of the design meeting in relation to design information differed, hence likelihood of disparities in how the team accomplished navigation interaction. This stems from the fact that demand for navigating information often aligns to both the structure and use of information during the meeting session (Jul and Furnas, 1997; Nurminen and Oulasvirta, 2008). Secondly, the social practice enacted by the team in relation to navigation may have resulted in peculiarities of accomplishing the navigation task, especially involvement of the participants. Indeed, the decision of the meeting facilitator (navigator), either to engage others or unilaterally execute the navigation task generally aligns with the teams' workflow during the meeting session. As argued by Orlikowski (2000) engagement of specific media, be it information content or display medium, is tied to both the team's practice as well as the capabilities afforded by the media. Thirdly, navigation tools afforded by the medium (i.e., software application), availability of input devices as well as interface and size of the display medium might have accounted for the discrepancies in realising the navigation task. For instance, as asserted by Nurminen and Oulasvirta (2008), the size and interface of the display medium contribute to how well navigation task is accomplished in a three-dimensional environment since these characteristics often tend to inform the ease with which users manoeuvre the information and interact with its content.

The finding appears to differ from earlier observations by Mehrbod et al. (2019) and Tory et al. (2008), who observed evidence of uniformity in the approach of executing navigation task during a design coordination meeting session irrespective of type of information representation and display medium utilised. The discrepancy in the approach of navigation task may be a result of the Smart Overly display medium utilised by the design team during the design coordination meeting, since interface of the visualisation medium had touch-sensitive capability whereby other participants could easily walk to the display medium and search for information via hand-touch. Again, the social practice of the team underpinning the design coordination meeting might be different in terms of how participants engaged with content of the design. In design coordination meetings, since participants are from different disciplines and specialties, the desire to interrogate certain design decisions might be higher, hence the individual's involvement in engaging with the design information. Consequently, irrespective of what capabilities of the media (information content and display) might be available to support navigation, how the design team intends accomplishing the navigation task needs to be considered as well to ensure that thorough interrogation of the design content is done during the meeting session.

The findings showed that participants in 3D CAD rendering mediated meeting with SmartScreen displayed medium rarely encountered bottlenecks when navigating the information content. Although rare, bottlenecks in navigation tended to significantly shape the flow of interaction in relation to use of information, nature of engendered conversations and member participation. The indication is that while navigation served as a vehicle to access relevant details of design information needed to inform participants' discussions on design issues, it also has the tendency to mar the information needs of participants during the meeting session if not well executed. The premise is that the act of searching information represented in 3D CAD format where content is static coupled with its presentation in 2D medium demands a wide range of inputs, including expertise of the navigator, availability of user-friendly navigation tools and input functionalities to successfully realise the anticipated goals. Deficiency in any of these inputs is likely to derail the gains navigation seeks to offer in supporting the team's interactions. Hence, the emergence of navigation challenge experienced in the design team could be attributed to both the technical skills of the navigator in manipulating views on screen as well as inadequate navigation functionalities afforded by the software application, since the PowerPoint presentation application media lacked advanced manipulative tools to easily browse and unveil hidden details of the 3D CAD rendering information representation.

This finding corroborates earlier observations on navigating digital information (e.g., (Tory et al., 2008; Cavka, 2010) that navigating digital information in 3D format continue to pose a challenge to users during team meetings. Therefore, wide range of issues become relevant in ensuring that navigation task is enhanced. These include improving information details and availability; simplifying navigation task by employing user friendly and touch-sensitive interfaces and providing more manipulative tools and input controls to aid information searching. Besides, improving the competencies and manipulative skills of participants in terms of interface familiarity and use of navigation tools as well as input devices are key to inject needed confidence expected of navigators in digital environments during the meeting session. As pointed out in prior studies (e.g. (Tory et al., 2008; Cavka, 2010; Jul and Furnas, 1997), provision of adequate support in the form of enhanced interface and information design simplify and introduce dynamics in the conduct of navigation interaction. Hence, the user is provided with a variety of options of navigation manoeuvring and input controls likely to reduce difficulties often encountered by participants finding and searching for design content in digital representations.

This section has discussed navigation interaction in relation to findings of the study, arguing that navigation supports varying goals of the design team during the design meeting, however, accomplished differently in different information representations and display medium due to design content, capabilities of the media, and social practice of the team as well as expertise of the users.

5.4.3 Gesturing at design information

The findings revealed that gesturing appears to be the richest interaction with design information, since it pervaded all the team's actions and communication instances during the meeting session. The design team employed gestures to mediate various functions, including referencing design information, directing attention as well as navigation. Besides, gestures supported participants to describe features of the design, explain design rationales and evaluate their appropriateness in relation to design requirements. In this case, the design team considers gestural action as a catalyst facilitating engagement and incorporation of varying dimensions of design information into their deliberations. Interspersing gestures while discussing aspects of the design information generally ensures that relevant content is integrated to help convey and query design ideas as well as situate on-going conversations within the context of underlying segment of information.

This finding aligns with earlier observation by Tory et al. (2008), that gestures are generally predominant mode with which the design team interact with information. Since gestural interaction emerge in different forms, participants are provided with a range of opportunities to interact and integrate different content of information into their current design discourse. Detienne and Visser (2006) also noted that gestures served as resources in producing intermediary representations (design artefacts), hence occupy larger portion of interactions among participants engaged in collaborative design activity during design meetings. Accordingly, since the current state of the design information serves as object in a flux whereby varying interactions and engagement among participants in the design team are expected to improve its current state, organisation of collaborative activities towards transforming the design content need to ensure ample opportunities are available for gestural interactions during the meeting encounter.

Moreover, the results suggested that the design team employed different forms of gestures to interact with design information during the meeting session. Gestures including pointing, two-finger indication, parallel indication and interlocked indication were observed. Since the design team supplement their talk and information representations with gestures in communicating the complex array of information defining the design, use of different types of gestures generally ensures that participants become accustomed to relevant details of the design needed to inform their discussions. Besides, as argued by Visser (2009), different forms of gestures are sometimes combined to effectively convey the new information due to their complexity in understanding the design. For example, while pointing gestures were predominantly used to reference design information while describing features of the design and explaining rationales underpinning design choices, parallel indication gestures (gestures with two hands spread in parallel) were mainly useful for describing spatial relations of design elements (Section 4.54).

The finding is consistent with previous investigations on gestural actions in design team's interaction with media (e.g., Visser, 2009; Murphy, 2005; Tory et al., 2008; Visser and Maher, 2011), that participants in design teams often employ wide array of gestures as informational resources to supplement the existing information to meaningfully engage with the design within the context of their interaction. For instance, Murphy (2005) in his study on use of gestures, talk and information representations in imagining a building in terms of form, function, and operation, noted that static nature of the information representation, coupled with limitations associated with two-dimensional display of the design necessitated that participants augment available information with varying forms of gestures depicting different characteristics of the design. Consequently, how these varieties of gestures are tied together within the context of the existing information and ensuing conversations as participants interact around the design information is critical to ensuring that essential dimensions of the design are adequately engaged with during the interaction process.

The findings suggested that gesturing towards design information varied across different information representations and presentation medium in terms of richness. The variations in gesturing interaction tended to centre around VR model mediated and 3D CAD rendering SmartScreen displayed mediated interactions. According to the results, gesturing at 3D CAD renderings was generally more revealing compared to the VR model as all the types of gestures identified in the team's workflows emerged while participants interacted with the information. Besides, a lot of screen-based gesturing activities occurred around the design information via the SmartScreen display medium to support range of tasks, including describing, explaining, and evaluation of existing or proposed solutions.

The richness of gestural interactions around the 3D CAD rendering SmartScreen medium in relation to the VR model wall display medium could be attributed to many reasons. Firstly, the interactive nature of the SmartScreen interface might have informed intensity of gestural actions around the display medium, since participants often gestured directly or nearer to the screen to engage with specific aspects of the information. By easily interacting with content of the design information via hand or pen input due to the touch interface capability of the medium, the opportunity to fluidly mix hand movement and manipulation of the information became possible for the team members (Ardito et al., 2014; Fard, 2006; Mehrbod et al., 2019).

Secondly, size of the screen interface and amount of information displayed to aid meaningful interaction may have informed variations in richness of gesturer interactions of the SmartScreen medium in relation to wall display medium. Since the screen size of the SmartScreen was generally smaller compared to the wall display medium of the VR model, smaller amount of information could be referenced while discussing issues around the design. Hence, more gesturer and manipulative actions may have to be performed to enable participants engage with varying aspects of information while attempting to understand and develop the existing design. By contrast, the wall displays medium provided a wider field of view, enlarging the size and content of the information. Accordingly, participants can see adequate amount of information needed to inform meaningful discussions without necessarily engaging in frequent gestural actions to supplement their information needs. This means participants had opportunity to reference aspect of the design remotely without essentially crowding the wall interface to secure attention of their colleagues. As reported by Issa et al. (2007) in their work on usage of interactive workspace in team meetings, that enlarging size of spatial data often provides ample opportunity for users to relate well with the information, as they can see the various aspects of design content unveiled. Hence, size of the display medium is essential to inform nature and intensity of gestural actions incorporated in the team's conversations around the design.

Thirdly, the larger number of participants in attendance during the 3D CAD rendering SmartScreen displayed mediated meeting compared with the VR model mediated meeting might have increased gesturer interactions around the 3D CAD rendering media. In team interactions, participants are required to secure alignment of their colleagues while supplementing their talk and design information with gestures for meaningful conversation, since other members are expected to respond by criticising or building upon the ensuing discussion (Murphy, 2005; Heath et al., 2000). Since participants needed to be involved in conversations around the design, access to relevant information demanded that they engaged more in screen-based gestural interactions to position relevant content of information within the interactive space of the team as pointed out by Murphy (2005).

Fourthly, the nature of the design task coupled with phase of development might have contributed to richness in gestural actions. The design represented by the 3D CAD rendering was in its conceptual stage, hence the need to supplement participants' talk and available information became inevitable since relevant characteristics of the design might be readily available to understand the design in its entirety in terms of structure, function, constructability and operation. Consequently, possibility of more gestural interactions occurring around the 3D CAD rendering may be higher compared to the VR model which was at the design development stage. Besides, the 3D CAD rendering represented an aerial walkway design which demanded more interrogations of design choices in various dimensions including safety, ergonomics, sustainability, cost and constructability.

These findings appear to differ from earlier observations by Tory et al. (2008) in their study on interactions with design artefacts that minimal variations existed between various forms of information representations in terms of gestural interactions. The discrepancy may be due to the nature of information representations and displayed medium employed as well as the nature of the design meeting and the evolving design. In the case of Tory et al. (2008), content of design was mainly represented in the form of 2D plans, 3D digital models via non-interactive projector screens and 3D physical models. Hence, differences in inherent limitations in amount of information revealed to describe the design may not be vast since they reveal details on spatial relations and exterior information of the design. However, in the current study, extensive variations in relation to form of representations (3D CAD rendering and VR model) as well as display medium (large non-interactive wall display and interactive SmartScreen display) exist in terms of amount of information represented to define the properties of the design, suggesting variation in intensity of gestural interactions as supplementary information to aid understanding of the design. For instance, the VR model reveals larger amount of information defining the design, including form, interior features, exterior features, aerial overview of the design, interior spaces in large scale compared to the 3D CAD renderings.

Consequently, for effective integration of design information into the term's discourse around the design, whether aided by gestural interaction or form and display of information representation, large amount of information defining the design need to be revealed for meaningful conversations among the team members. Besides, since users generally relate well and incorporate design information fluidly when the interface connecting them to the information is interactive, more effort should be made to assemble displays with interactive interfaces large enough to facilitate rich interactions, both with the design content and participants in the design team.

The data showed that the design team accomplished gestural action using different methods, including remote gesturing and direct gesturing. Remote gesturing (gesturing towards design information at a distance) was more often associated with the VR model wall display medium. By contrast, direct gesturing (touching the displayed medium via hand or pen) was generally aligned with the 3D CAD rendering SmartScreen display. As previously discussed, participants in the design team generally employed gesturing to integrate existing information into their deliberations around the design, and as a resource to augment inherent limitations, both in the information representation and their talk. Hence, since variations exited in amount and detail of information communicated by the VR model in relation to the 3CAD rendering, as well as their medium of display, approach in interacting with the design content via gesturing may differ.

This finding is consistent with Tory et al. (2008), who reported that participants employed both remote and direct gesturing techniques to reference design information as well as secure attention of team members during the meeting session. However, unlike Tory et al. (2008), who observed more remote gesturing interaction in relation to the computer screen, there were more direct or touch manipulations with the interface of the SmartScreen display compared to remote gesturing during the meeting session. The difference may be due to the touch-sensitive capability of the SmartScreen compared to the computer screen. As maintained by Fard et al. (2006) and Mehrbod et al. (2019), participants often tend to gesture at design information on screen via hand touch as the interface provides flexibility to manipulate relevant aspect of the information essential to inform conversations around the design.

5.4.4 Annotating design information

The act of annotating design information has been observed as one of the key actions with which design teams employ to comment, add extra information to existing design as well as communicate design recommendations, since this aids to capture, store and manage contributions of participants during design meetings (Aubry et al., 2007; Lenne et al., 2009; Li et al., 2009; Marshall, 1997). However, although annotation serves as a vehicle to extend existing knowledge of the design, variation on its usage during design meetings has been reported in literature, suggesting evidence of dynamics in its relevance in design meetings (Aubry et al., 2007; Fard, 2006; Mehrbod et al., 2019; Tory et al., 2008). For instance, while prior studies (e.g. Fard, 2006; Mehrbod et al., 2019) observed more frequent annotation interactions on digital design information in collaborative design meetings. Tory et al. (2008), in their study to explore variety of approaches with which participants in design teams interacted with design representations, noticed rare cases in which the team members digitally marked on the design information, citing difficulty with the use of interactive SMART overlay technique employed by the team as well as skills in manipulation of pen strokes as the underlying reasons. While Tory et al. (2008), ascribed sparse annotation interaction with design information features and operation of the display media, Mehrbod et al. (2019) attributed extensive marking up on design information to capabilities and ease of use of the interactive display as well as participants' awareness of the use of annotation as temporary objects to the design information. Accordingly, features of media employed to display design information coupled with participants' expertise in its usage as well as purpose of use of annotation in design meetings appears to be essential considerations in a team's use of annotation.

In contrast to the previous observations, although annotation was found to be a key act with which the design team interacted with design information, specifically, VR model mediated meeting, the findings indicated that emergence of annotation action was occasional to summarise and document design decisions during the meeting session. The suggestion is that the design team appear to attach some relevance to annotation in terms of its usage, hence, strategically employed to perform unique functions in their interaction with the design information. The premise of occasional use of annotation on design information could be attributed to the way in which the design team structured their workflow to incorporate annotation in the review of design information (VR model). In line with their practice, participants in the VR model mediated meeting consistently climaxed their discussions on the current design topics with annotation. For example, participants often remarked when discussions on design issues were ended: "Can you capture what we have discussed?" (Section 4.4.5).

By incorporating annotation in such situations, the design team had opportunity to capture comments and contributions of participants on design issues, hence making the quest for annotation inevitable as the team desire to accurately record and relay feedback to the designers as well as the reviewers. Moreover, in VR model mediated meetings, the goal of reviewing the information content was mainly to identify potential design errors, resolve issues identified and provide response in the form of reports. Therefore, capturing the summary of design issues via annotations became relevant in the team's design review workflow. Hence, purpose of the design meeting as well as condition of the design information appear to be essential in informing significance of annotation in the team's workflows. Overall, the discrepancies in terms of extent of incorporation of annotation on design information as discussed, both in prior studies and the current findings, could be attributed mainly to the goal of the design meeting, their workflows, features and usability of the display application and media as well as expertise in manipulating annotation and mark-up tools afforded by the media. Consequently, optimum utilisation of annotation interaction with design information requires that underlying premise of its usage be made explicit to all participants in the design team, since knowledge of its role has the tendency to inform how well participants and the team engage in the action to realise its desired outcome as indicated by Mehrbod et al. (2019). Again, planners of design review meetings supported by various digital media enhanced with annotation and mark-up capabilities need to ensure that mode of utilising annotation and mark-up tools as well as its manipulation are user friendly to reduce the learning curve and ensure adequate application of the relevant tools. By this way participants will be more confident with the use of the annotation and mark-up tools and richly employ it to extend the design knowledge thereby enriching the development of the evolving design.

Many prior studies on purpose of annotation interaction in design meetings have revealed that participants employ annotation and mark-up action to serve a wide range of needs, including capturing, storing, communicating and retrieving design information (e.g., Mehrbod et al., 2019; Tory et al., 2008). In addition to these findings, the results revealed other two distinct roles annotation action was performed during the meeting session. Firstly, the annotated design information occasionally structured the team's workflow, since conversations engendered around the annotation triggered other follow-up tasks. The suggestion is that annotation became both a means of engaging with the VR model representation of the design as well as an object of interaction with which participants undertook other actions relevant to thoroughly address the underlying design issue.

Secondly, the design team used period of executing annotation task as a forum for discussing varying interpersonal issues. As discussed previously, in the VR model mediated meeting sessions, annotation task emerged to bring closure on the arguments and negotiations engaged by the team members while addressing design related issues. Accordingly, since demand for participants' contributions on the design has ended, period of annotation provided opportunity for participants to deliberate on matters of personal or group interest. Another reason of switching from core goals of the design project to interpersonal interactions could be due to the interesting remarks made in connection with nature of the generated digital photos as well as form and structure of the side-sketch annotations. For example, participants, while observing the technical execution of the annotation in relation to creation of the digital 2D photos and the attendant side-sketches, often remarked:

> "…this photo is nice, it looks real"; "wow! it looks like a real picture" … and …" this sketch is very detail" (Section 4.4.5).

As Bales (1950) asserted, participants in project teams seeks to operate both in their core functional activities and socio-emotional needs of members as well as wellbeing of the group. Hence, maintenance of balance between task contributing to the team's design goals and their social needs ensures that participants are relieved of tension build-up which might have arisen due to their prior exchanges in relation to the design issue. As pointed out by Maftei (2015), that participants perception and orientation to novelty of digital media or design information often spikes humour in their social interaction during digitally supported design meeting sessions. Consequently, ability to look beyond the normal usage of annotation as a mechanism for the capture and storage of the team's comments on design issues for its social-emotional benefits is critical to enriching the participants interaction during the meetings supported by technologies considered novel in their package.

The results revealed variations in annotation action across different media in the team's meeting sessions. Annotations in VR model mediated meeting sessions were found to be more revealing and structured compared to the 3D CAD rendering media. Since annotation serves different functions in terms of capturing additional design information, relevance of annotation in design meetings mediated by the VR model representation of design information may differ from the 3D CAD rendering SmartScreen supported design meeting. Besides, the application software (i.e. Enscape plug-in for Revit application) employed to facilitate presentation of the VR model had annotation and mark-up functionalities to aid annotation of the information compared to the PowerPoint application utilised in the 3D CAD rendering mediated meeting. Although, decision to annotate design information may be informed by the team's goal in relation to the design meeting as discussed earlier, availability of facilities to support annotation and mark-up of design information suggested a likely possibility of annotation action to thrive in the VR model mediated design meeting.

This finding appears to be consistent with Mehrbod et al. (2019) observation that, variation exist in how participants annotate design information in different application medium. For instance, in their study on how participants in design coordination meetings interacted with building information modelling (BIM) tools, Mehrbod et al. (2019) noticed changes in annotation interaction across different applications such as Navisworks, Revit architecture and PDF presentation as well as the Smart Overly display interface. Hence, ensuring richer annotation in design meetings supported by digital media necessitates that facilities needed to support the action, both in terms of software application as well as display medium are made available for the team members. By this, participants may have the opportunity to mediate their social practice in relation to annotation of design information.

Moreover, the findings suggested that the design team approached annotation task in the VR model mediated meeting as a collective endeavour where individual members provided range of inputs towards its accomplishment. The technical aspect of annotation was executed by one member (annotator) while other members either initiated the annotation process or provided needed input to ensure that relevant details of information are captured. Since the design team has enacted annotation action as a as a tool to summarise and document design decisions during the meeting session, content of information captured needed to reflect the team's overall position, hence their collective involvement ensured that required detail of annotation are documented and conveyed accordingly. Besides, by relying on a single keyboard and mouse as input device to annotate and mark-up the VR model, the need for participants to work together seems to be one of the available options to accomplish the annotation interaction.

The analysis indicated that the design team preferred annotating VR model on a separate 2D digital copy of the model instead of the original version. By isolating incorporation of additional information from the exiting VR model, the design team ensured that original design information is preserved without altering its status during the meeting session. The decision to detach participants' comments from the original VR model could be linked to several reasons. Firstly, the design team had adopted building information modelling (BIM) methodology to inform their workflows, therefore the responsibility of modifying information content became a preserve of the author(s) (BSI, 2014:14). Secondly, a design feature has multiple attributes including function, form, ergonomics, aesthetic, constructability among others, which could be referenced during discussions for different purposes. The same element of the design could attract varying comments from the team members which need to be attended to separately without interfering with prior commentaries. Hence, separating annotation object from the original design content ensures that other issues pertaining to the underlying design are addressed accordingly without interfering with others referencing the same target. This ensures that the challenge of annotation overlaps as argued (Li et al., 2009) to hamper orderliness in documenting and interpreting design knowledge are addressed. Thirdly, availability of annotation and image generation tools provided by the Enscape plug-in for Revit application may have motivated the decision to separate annotated information from the main VR model since opportunity for creating the digital 2D images was readily available. Finally, usability of the application coupled with expertise of the annotator could also account for the practice of applying annotation on a 2D digital version of the VR model. The results corroborate earlier findings of Ding et al. (2009) that participants in design teams generate snapshots of 3D digital models to annotate the design information, however, differed from Tory et al. (2008) observation on how participants annotated digital 3D images in a design meeting. Tory et al. (2008) in their study on characterising interactions with design information in a design coordination meeting noticed that participants in design meetings annotated and marked up directly on the design information as they commented on design issues. The discrepancy could be a result of the goal of the design meeting and purpose with which annotation was carried out to, since in design coordination meetings, participants from different disciplines attempt to clarify and modify issues in their respective domains in real-time to enable others progress in their discipline specific aspects of the design as observed by Mehrbod et al. (2019). Besides, the methodologies underpinning workflows of the two design meetings may differ, hence informing their social practice in relation to how annotations are applied on design information. For instance, as pointed out by Wang and Dunston (2008), both annotation and mark-up functionalities afforded by a media and the environment under which they are deployed are essential to inform the approach adopted to add extra information to the existing design. Accordingly, the decision to isolate annotation from the object during design meetings needs to be aligned, specifically to the purpose with which annotation interaction is enacted in consideration with the team's project delivery method, thereby realising the gains expected of annotation action during design meetings.

The results also revealed that the design team employed different techniques, including side sketch (annotation positioned away from the target object) and annotate drawing (annotation attached directly onto the target object) to capture summary of design discussions. Annotations are performed to fulfil different functions in relation to content of the design information, hence the form of annotation tailored to reflect the actual information being conveyed (Lenne et al., 2009). Since, the design team members addressed various issues on the design information with different comments, variations in annotation technique became necessary to reflect the team's position. Besides, annotation and mark-up facilities of the Enscape plug-in for Revit application, coupled with flexibility in its usage may have provided opportunity for the participants to add varying forms of annotation on the VR models.

This finding seems to differ from Tory et al. (2008) and Mehrbod et al. (2019), who reported in their subsequent studies on interaction with digital information during design meetings that, participants mainly attach annotation directly onto the digital 2D drawing. This variation may be due to the annotation and mark-up facilities provided by the Enscape plug-in for Revit application employed to display the VR model, as tools essential for producing digital sketches to communicate feedback on design information were readily available. Besides, skills of the annotator could be a factor, since ability in manipulating annotation and mark-up tools on design information has been found to affect how participants' comments are added to the existing design (Tory et al., 2008). Moreover, differences exist between design coordination meetings and design review meetings in terms of goal accomplishment and activities. While design meetings often concentrate on creating design knowledge collectively during meetings, design coordination focus on understanding the design and making decisions around design choices from viewpoints of multi-disciplinary participants. Hence, possibility of adding extra information in the form of sketches towards creation of new knowledge appeared to be high in design review meetings compared to design review meetings as reported by Tory et al. (2008). Although production of additional information in varying content and level of detail are essential to transform the evolving design, techniques for their accomplishment need to be aligned to annotation facilities of the display medium and the goal underpinning the meeting, since these conditions tend to aid how much and in what form extra information via annotation could be added to enrich the existing design.

Moreover, the findings showed that design team richly used the annotation and mark-up tools of the Enscape plug-in for Revit application through mouse and keyboard inputs to accomplish the task. Presumably, the decision to apply the annotation and mark-up tools via the use of mouse and keyboard input devices may be due to the occasional use of annotation mechanism to summary deliberations on prevailing design issues, since varying amount of content and information details had to be documented. By using the mouse and keyboard inputs, the annotator may obtain flexibility to manipulate the various annotation and mark-up tools required to define form and content of the additional information communicated. As acknowledged by Tory et al. (2008), that the ease with which participants in design meetings operate input devices are fundamental to the nature and amount of mark ups produced on a digital representation of design information. Another explanation accounting for the use of mouse and keyboard inputs could be linked to nature of the display interface, since the wall display as well as the multi-projector screen interfaces relied on to mediate their engagement with the VR model were non-touch sensitive. Accordingly, direct input of the annotation and mark-ups tools via hand and pen assignment, whereby participants in the team are provided opportunity to add extra comments on the VR model during their deliberations could not be a likely option to produce the summary report of design decisions per the practice of the team.

5.5 Disruption of team's workflows

The findings revealed that participants occasionally experienced disruptions in their workflows while attempting to navigate virtual information and introduce new information during the meeting session. Generally, exhibition of new information via mobile devices and 2D paper sketches halt flow of conversations and changes team members' participations in conversations about the design. This suggests that digital arrangements to support information generation and access are not robust enough to facilitate sharing and accessing of information during the meeting session. The emergence of disruptions could be attributed to several reasons, including unavailability of mechanisms in the digital space to aid transferring private information to a shared display, lack of navigation functionalities in the visualisation application and inadequate navigation tools. In addition, inadequate skills of participants in navigating digital information could lead to bottlenecks in the team's workflows. This stems from the fact that successful navigation requires performance of serials of tasks including wayfinding and motion controls to locate desired information content as asserted by Jul and Furnas (1997).

This finding confirms prior observations on team interactions mediated by digital spaces (e.g., Cavka, 2010; Fard et al., 2006; Fard, 2006; Tory et al., 2008), that participants in the design team occasionally experience disruptions in their workflows while navigating digital information and introducing new materials during the meeting session. Accordingly, information representations provided to mediate actions and activities of participants need to be well developed and displayed to reduce and simplify navigation operations. Besides, efforts had to be made to ensure that visualisation applications utilised are rich with relevant and usable navigation tools. By this, demand for obtaining specific content of the design essential to enhance current discourse about the design will be met thereby enriching interactions in the team's workflows. Another implication is that the digital space had to be enhanced with additional mechanisms to facilitate introduction of new information when the need arises. While these provisions are key to maintain flow of interaction while accessing information, the expertise of participants in navigating digital information equally need to be enhanced to achieve this fete. The next section discusses findings on interplays between types of interactions emanated during the meeting session.

5.6 Interplay between types of interactions

The findings revealed interplays between types of interactions both within and across the different categories of interaction (verbal and non-verbal). Generally, gesturing and viewing actions were fluently intermixed with all the essential actions, including describing, navigating, explaining, evaluating, sketching and annotation during the meeting session. Participants seamlessly switched between viewing and gesturing with different actions while interacting to develop the design. This suggests that both verbal and non-verbal actions in relation to the media important in developing the design. The emergence of rich interplays between different types of actions during the meeting could be attributed to complex and situated nature of interaction between participants and the material environment of their work as asserted by Jordan and Henderson (1995). Generally, circumstances with which participants produce meaningful actions may differ and as such successful accomplishment may be tied to exhibition of other actions for meaningful conversations.

This finding confirms observations in previous investigations on interactions in mediated environments (e.g. (Fard et al., 2006; Fard, 2006; Maftei and Harty, 2015; Mehrbod et al., 2019), that participants in fluently intermix different actions while interacting, both with the media and with each other developing the design. For instance, Maftei (2015) noticed that verbal and non-verbal behaviours of participants in the design are generally intertwined making intermixing natural while orienting to the media. This implies that large array of digital resources in terms information representations, visualisation applications and display medium must be assembled while planning design meetings in the digital space to ensure successful mixture of relevant behaviours needed to transform the design.

The findings further revealed variations in interplays between types of interactions across different media during the meeting session. According to the findings, interplays between viewing, gesturing, navigating and annotating actions were more aligned to the VR model mediated meeting when explaining and evaluating the design, while that of viewing, gesturing, navigating and sketching actions was richer in the 3D CAD rendering SmartScreen mediated meeting. For instance, participants seamlessly switched between viewing, gesturing, navigating and sketching actions while explaining and evaluating design decisions during the 3D CAD mediated meeting session. The variations could be attributed to differences in capabilities of the information representation, visualisation application and the display medium supporting the undertaking of the ensuing actions. As discussed in the preceding sections, VR model reveal different characteristics of the design compared to the 3D CAD rendering, hence set of interrelated actions needed to adequately interact with each of them may differ during the meeting session. Again, the visualisation application (Enscape plug-in for Revit architecture) of the VR model was enhanced with walkthrough/flythrough navigation tools as well as annotation and mark-up tools hence facilitating transition between navigating, annotating and the common actions (i.e., viewing and gesturing) compared to the 3D CAD rendering visualisation application which appeared to be limited in navigation and annotation tools.

This finding aligns with Mehrbod et al. (2019) observation in their work on use of BIM tools, that participants variation exists in the interplays between different non-verbal actions different mediated environments during the meeting session. In addition to Mehrbod et al. (2019) remarks, the current study noticed that these variations extends to emergence of explanative and evaluative communication task during the meeting session. Hence, since different communicative task fluidly intermix with different set of non-verbal actions in specific media spaces, efforts need to be made to ensure that facilities deployed during the meeting session adequately facilitate relevant interplays required to enrich interactions within the digital space.

This section has discussed that interplay exist between types of action while interacting to develop the evolving design, however, differ across different media during the meeting session. The next section provides summary of the discussions made in this chapter and introduces the proceeding chapter of the thesis.

5.7 Chapter summary

This chapter presented the findings emerged from the video data and referenced chapters 2 and 4. The chapter discussed the verbal communications and non-verbal interactions in relation to the media and how they were supported by media in the digital space drawing on mediated interaction approach as well as use of technology in practice lens to explore actions and activities of team members and how they were enabled by media in the digital space. This discussion included an exploration of information representations and display medium utilised to mediate participants' communicative tasks as well as interactions with the media. Besides, the findings discussed disruptions in the team's workflows as well as interplays between the various types of interactions emerged in the digital space. The exploration of the interplays helped to identify the relevant interconnections existing between different types of actions during the meeting session.

Based on these findings, implications to inform practice in the area of meeting planning and designing of effective digital spaces to facilitate interactions in the design team were given. The implications were based on the context within which interactions ensued and hence were provided in the form of recommendations to enrich actions and activities of the team members during the meeting session. The next chapter presents the conclusion of the study.

Chapter 6: Conclusion and Recommendations

6.1 Introduction

This chapter reiterates the aim and objectives of the PhD and provides conclusions on the research findings in relation to team interactions enabled by media in the digital space within the context of architectural design meetings. Besides, the chapter presents and discusses contributions of the study, limitations of the research as well as implications and suggestions for future research.

6.2 Review of research aim and objectives

This research was conducted to explore nature of interactions of team members in the digital space and how they are supported by media during design meetings in an architectural design practice. This involved a thorough investigation of verbal and non-verbal actions emerged in the digital space and their effect on information representation and display medium during digitally mediated face-to-face design review meeting sessions. The overarching concern of the study is that current approaches to explore nature of interactions mediated by digital media (i.e., information representations and display medium) that focus on macro level verbal and non-verbal actions of team members, and quantify their occurrences provide little opportunity to qualitatively explore the fine details of interactions within the complex and fluid digital space. Hence, a more comprehensive approach that explores participants' verbal and non-verbal actions at the micro level within the context of their emergence is more useful to allow the fine details of the team's interactions to be captured.

The aim of the thesis was addressed by first, conducting a critical review of relevant literature on conceptualisation of team interactions mediated by digital media (information representation and display medium) as well as existing characterisation of digital media within the context of face-to-face design review meetings, and also the empirical investigation of the various interactions with information representation and display medium in the design review meeting session; and second, through the use of technology in-practice lens (UTIL) and mediated interaction approach (MIA) to explore the nature of verbal and non-verbal actions that unfold to communicate and develop the design, and how specific features of the digital are used to mediate these actions in a series of video recorded design review meeting sessions. Five objectives were set to achieve the aim of the research and were addressed as follows:

Objective 1: To identify the forms of digital media mobilised and examine the salient features utilised to facilitate the actions and activities of team members during the design meeting session.

The research attempted to distinguish the medium of presenting design information from the information representation in terms of how they support interactions to more closely understand the types of actions and activities that unfold in the digital space. This distinction was deemed useful since both the information representation and the display medium have distinct features which may not offer the most exciting experience required to promote dynamic exchanges in the design team in all instances. The results revealed, in general, evidence of distinction between the medium and the representation of design information in terms of how they supported or disrupted emergence of specific types of interaction during the meeting session. The features of the information representation such as photorealism, walkthrough, and navigable stimulated more discussions about the design information. Contrary, characteristics of the medium, including touch-sensitive interface and static large displays influenced how participants experienced and understood aspects of the information representation needed to inform their deliberations on the design issue. Besides, these characteristics of the medium relatively tended to shape the dynamic exchanges ensuing among the team members and with the media (information representation and display medium).

The utilisation of the medium to support participants' actions and task inform the approach and techniques of the design team to interact with design information and accomplish a task. This domain of the media in supporting actions and activities of participants became evident as capabilities of the medium, including touch-sensitive interface, virtual walkthrough/flythrough, annotation and mark-up, as well as large display size contributed in shaping how specific features of the representation, such as interactivity, real-time viewing and manipulation were used to support realisation of specific tasks.

In contrast to the medium, the representation aspect of the media is tied to the type of action to be undertaken by the team members during the meeting session. This was evident as participants exhibited different types of fine-grained actions in their attempt to engage with content of design information including VR model and 3D CAD renderings in their discussions. Accordingly, accounting for both the type of action required and how it is to be performed when mediating interactions of the design team is key to ensuring that essential aspects of the action are adequately accomplished, since they play different roles in facilitating emergence and accomplishment of tasks during the meeting session. Large display and touch-sensitive interface richly facilitated accomplishment of evaluative, descriptive, annotation and gestural actions.

It was also found that forms of media mobilised to mediate the communications and actions of the design team vary according to the level of detail provided by the information representation and the extent of interactivity of the design content required for accomplishing the task. This was established as the team members fluidly assembled varying forms of representations and display medium, such as VR models, 2D digital plans, elevations and sections to modify their understanding and experiences of the design information. For example, the VR model, which was relied on as the main representation was limited in terms of providing opportunity for analysing the spatial arrangements of the design. Hence, the team members introduced the 2D plans and elevations to clarify issues with the arrangement of the design elements.

Design team members richly utilised the interactivity features of both the medium and the representation in responding to emerging design issues since the project context and requirements do not allow for more extensive disruptions at the team level. Issues bothering on design decisions requiring shared understanding and modification begun to develop as conversations around the design unfolded and needed to be sustained, hence the interactivity features of the media became supportive in deepening the discussions around the design. However, there were noticeable variations in terms of how the interact features of the information representation and display medium stimulated or disrupted the dynamics in the flow of interactions. The size and touch-sensitivity features of the medium incited richer and dynamic exchanges as participants attempted to modify their experience and comment on the design information. In some breath, features of the media, specifically, touch-sensitive interfaces and display size made emergence and accomplishment of some verbal and non-verbal actions desirable and others challenging or disrupting.

Objective 2: Explore how the design team uses digital media to mediate their actions and activities during the design meeting session.

One of the objectives of the research was to identify and characterise types of medium and representation, and also explore how they are used to support specific types of interaction in the design meeting. The research findings reveal that the design team mobilised personal technologies to support their communication instances and accomplish their task. The findings suggest that the design team employed personal technologies in two distinct ways, including serving as main medium for supporting visualisation, and supplementing existing technological set-up of the digital space. The use of personal mobile devices to augment current technologies in the digital space results from limitations in the existing setup of the digital space. Because existing set-up of the digital space appear to be deficient to support visualisation of additional information, the users often resort to the use of auxiliary (personal) mediums to share additional information during the meeting session. However, the findings indicate that introduction of new information via participants' personal devices disrupt current conversations about the design, since discussions had to be stopped for individual members to view and familiarise with the new information.

The use of personal technologies indicate democratisation in viewing and manipulating the existing and shared information for meaningful discussions. The reliance on personal technologies as sole medium to support participants' interactions is evident when team members ignore wall display medium setup of the digital space. Accordingly, through the reliance on touch screen interface, individual members obtain control of view set-up for specific information while engaging in conversations about the evolving design. Consequently, knowledge about both the mobilisation of personal devices in supporting the team's actions and tasks as well as circumstances of their emergence are key to ensure their effective utilisation in mediating the interactions of the team members.

In terms of the purpose of the use of the medium and the information representation during the team's interactions, the findings reveal that the design teams employ the medium to support accomplishment of different tasks including searching, visualising, manipulating, authoring, annotating and documenting design information as well as managing the team's workflow. The results further indicate that the design team mainly accomplish these goals through variety of capabilities of range of medium such as large single display, portable displays, touch-sensitive interface, annotation and mark-up functionalities, and navigation functionalities (virtual walkthrough/flythrough and view set-up tools) to support the actions and activities of the team.

With regards to representations, the results reveal that the design team generally use the information representation to inform design decisions, served as a source of reference to facilitate discussions about the design, and prompted undertaken of specific non-verbal tasks as these actions were occasioned by content of the information representation. Additionally, the study note that the design team mainly utilise the navigable, interactive and walkthrough functionalities as well as its photorealism and three-dimensional geometry (3D) of the representation to support their actions and communications. The reliance on varying characteristics of information representation is evident as participants fluidly intermix range of verbal and non-verbal actions while relating to different features of the representation. However, specific features of both the medium and the information representation also informed the purpose of use of the media in accomplishing tasks of the team. This became evident as participants mainly utilised, for example, the large wall display interface mainly for visualising design information. Since the wall display interface was not touch-sensitive, on-screen dynamic exchanges among the team could not be undertaken.

The study findings reveal that the design team enacted use of media based on their design review practice, and configuration of the media to support their actions and activities over the course of the meeting. The results of the study also suggest that how the design team customised the digital space and the media greatly inform how specific capabilities of both the medium and the information representation are used, and the approach adopted towards its utilisation. This is manifest in the undertaken of user-driven actions such as annotation and mark-up of digital copy of the VR model to preserve the original information as well as spreading a single information representation across a multi-projector screen. Again, the configuration of the medium informed the team's approach in interacting with design information as large display mediums supported group viewing, compared to the portable displays. This is evident in the team's reliance on mobilisation of their personal mobile devices to view, manipulate and interpret design information during the meeting encounter. The consideration of both the team's underlying workflows and configuration of the media are key for effective utilisation of relevant facilities of the media to support accomplishment of tasks during the meeting session.

The findings reveal that the technological set-up of the digital space did not encourage the participants to share additional information from their personal devices, deemed relevant to enrich discussions about the design among the team members. This is apparent in the team's practice of passing the new information around via personal devices for adequate familiarisation with the relevant content before usage during the meeting session. Hence, a means to mediate personal and shared displays in terms of information sharing is critical for public use of design information during the meeting session.

In terms of the types of user-driven actions and mechanisms employed to compensate or augment the experience and understanding of that information, the results show that the design team resort to sketching, use of content-rich and less navigable information as well as use of additional information via personal mobile devices (tablet and smartphone) to address limitations in both the representation and the display medium. The user-driven tasks were ad-hoc in nature and tended to respond to usability and affordance challenges of the medium as well as inadequate content of the representation while accomplishing a task. However, findings from the study indicate that undertaking of user-driven task tends to disrupt the flow of participants' current discussions and lowers their participations since the mediums supporting the ad-hoc tasks were generally smaller in size. This manifested when a group of participants had to gather around the 2D paper sketch to view the information or take-turns to look at the information via personal mobile displays.

Objective 3: Examine the nature of verbal actions that unfold in the design team and the role of the media towards its accomplishment during the meeting session.

The nature of verbal actions that unfold in the interactions of team members during design meetings mediated by digital media (information representation and display medium) and how they affect the use of specific features of the media were explored in the video recorded face-to-face design review meetings. It was found that verbal actions mainly involve shared understanding of the design content and addition of value to existing design decisions by iterative engagements of descriptive, explanative, evaluative and predictive tasks with continuous incorporation of varying gestural, viewing and navigation tasks via the use of different features of the information representation and display medium. These aspects of the verbal actions are discussed extensively in Chapter 5, but the main findings are provided below:

The design team developed shared understanding of the existing design decisions by fluidly transitioning between sharing of different forms of design information, undertaken of descriptive and explanative tasks intermixed with varying viewing and navigation tasks through the use of large display medium and mobile devices (smart phones and tablets) in both touch-sensitive graphical interface, and keyboard-mouse controls. This was noticed in the video data recorded (Section 4.4) on verbal actions of the team members employed to gain insight into the design content represented, visualised and interacted with through wide range of representational and display media during the meeting session. Within the conversations around the design information, lead designers attempted to provide adequate descriptions of proposed design decisions to enable other members familiarise with the design and better contribute to refine the evolving design. Consequently, as the lead designers described various details of the design, they needed to provide explanations alongside through the reliance of different features of the information representations, including the photo-realistic and walkthrough features VR model, the three-dimensional (3D) geometric and visual characteristics of the 3D CAD renderings as well as spatial arrangements of the 2D digital drawings (Floor plans, elevations, sections and details). The need to intersperse descriptions of design decisions with relevant explanations necessitated that participants incorporate and switch between varying forms of design content via fixed displays (wall display and touch-sensitive SmartScreen) and mobile devices (tablets and Smartphones) to inform understanding of the team members in relation to the existing design decisions (Section 4.4.3). Hence, to better understand the design decisions during the meeting session, the design team require opportunity to mobilise, view and fluidly switch between different forms of representations and display medium.

It was also realised that modification or value addition aspect of verbal actions of the design team were accomplished through iterative moves between evaluative task, predictive task and sketches with richer gestural and on-screen manipulative actions on different range of information representations, including virtual reality (VR) models, 3D CAD renderings, 2D digital drawings and hand drawn paper sketches.

Objective 4: Examine the nature of participants' interactions (non-verbal actions) with the digital (including information representation and display medium) and the effect of media towards its accomplishment in the design meeting.

The study sought to identify and examine the nature of participants' interactions (non-verbal actions) with the media (display medium and information representation) as well as effect of the media towards its accomplishment. The research findings reveal that non-verbal actions in relation to the design information mainly involve addition of information to improve the design decisions, searching and familiarising with different aspects of design information for informed understanding of design content by fluid transitioning of viewing, navigation, annotating, gestural and sketching tasks with interspersed descriptive, explanative and evaluative actions of varying design representations across different display media. The details of these non-verbal actions are adequately captured in Chapter 4, however, the key findings are outlined below:

The design team non-verbally provided additional or extra information to aid conversations around the existing design decisions and improve the content because there was insufficient content of the existing design information to provide enough detail about the functional characteristics of the design. This was realised through the video-recordings of the activities of the team members that attempted to annotate and gesture at aspects of the existing design towards improving its content during the meeting session (see Section 4.5.2; 4.5.4). Within the design meeting sessions, members in the design team across different representations, such as, the VR model, 3D CAD renderings, 2D drawings (floor plans, elevations and sections) and paper and pen sketches fluidly made gestural actions depicting various functions, including spatial layout, motion and constructability of proposed design elements as way of providing extra details to transform the existing design since limitations in the existing representations in terms of content failed to conform to the design requirements. Hence, delivering sound design decisions through provision of additional data-rich information in the team's design review encounter required exhibition of content-rich gestures, annotations and marking-up.

The findings indicate that gestural action is versatile in adding value and familiarising with design information as more participants involved in the process used varying forms of gestures, including pointing and parallel indication gestures to engage the design information and interact with the display medium. However, the results also revealed that gesturing differs across different characteristics of both the representation and the display medium in terms of their dynamics. The findings note that gesturing at design information via the large touch-sensitive display interface is richer as many participants adequately took turns to point to, spread hands to indicate shape, size or movement of design elements and functions on-screen as the team members flexibly manipulated varying aspects of the design information due the touch-sensitive nature of the display interface. This is evidenced by extensive on-screen gestural actions and exchanges among the team members as participants richly commented or added to prior actions while controlling the 3D CAD rendering via hand touch or pen input. The desire of participants engaging in on-screen gestural interactions with information representation around the SmartScreen interface could be attributed in part to their quest to control manipulation of information and provide input to enrich the design. The input control and manipulative capabilities of the medium can therefore be considered as essential ingredient in enhancing rich direct interaction with the information representation while communicating to develop the design.

In terms of annotating design information, the study revealed that annotation is an important dynamic act relied on to summarise, add value and document design decisions. Further, the results indicate that annotation is collaboratively accomplished through variety of methods and techniques, whereby the meeting facilitator solely performs the technical operations (utilisation of annotation/mark-up tools) using mouse/keyboard inputs. The accomplishment of annotation involves creating a digital copy of specific aspect of the VR model and applying annotation objects directly on the design information or as a side-sketch (see Section 4.4.5). The need for participants' collective involvement was evident in the performance of the annotation as successful execution of the task had technical aspect and social component to ensure that the team's collective decisions on design issues are adequately captured.

The research findings reveal that viewing is a ubiquitous and dynamic action with which the design team employed to familiarise with wide range of design information while attempting to undertake a task during the meeting session. The results show that the design team accomplish viewing task through different approaches and methods facilitated by large multiple and single displays as well as portable mediums.

In terms of approach, the findings reveal that participants view design information in three distinct ways, including group viewing, sub-group viewing and individual viewing. However, the findings also indicate that approach to viewing design information vary in different display mediums during the meeting session. The results note that group viewing occur in public displays (wall display, multi-projector screen and SmartScreen display), whilst sub-group and individual viewing emerge in personal mobile technologies (tablet and smartphones) and paper sketches. The decision to view design information introduced to augment existing information via participants' personal devices became manifest as team members viewed information in turns or crowded around the medium to familiarise with the information. In the case of techniques of viewing design information, the research findings indicate that the design team prefer viewing single information at a time on the display medium for optimum concentration. However, the findings reveal that the design team proceed viewing with the principal information (i.e., VR model and 3D CAD rendering) for general knowledge before switching to auxiliary information (e.g. 2D digital elevation views) for specific details over the course of the meeting. The variations in viewing practices in the design team give credence to suggest that viewing is a dynamic act in the team's workflow, which tends to be affected by nature and use of the design information, size and nature of the display medium as well as their social practice.

In terms of navigation, it was observed that the design team extensively searched to familiarise and understand varying details of design information because different perspectives and content of the proposed design were needed to enhance the experience of the participants in relation to existing design decisions. This was identified during observation of the video data as members in the design team fluidly viewed and navigated different forms of information representation, including VR models, 3D CAD renderings, and 2D digital drawings (floor plans, elevations, sections and details) to enable them appreciate proposed and make informed contributions to modify content of the design. During the meetings session, the desire to search and familiarise with information representation incited mobilisation of personal devices, creation and introduction of additional information, rich in complementing the inherent limitations of the existing information in terms of content and interactivity.

Furthermore, the results note that design team accomplish navigation task through different methods and techniques supported by the virtual walkthrough/flythrough capabilities of the medium, mouse and keyboard input as well as touch-sensitive interface of the mobile technology. The use of the touch as a form of input encouraged more dynamic exchanges among the team members compared to the mouse/keyboard controls. This was as a result of the individual members obtaining control in manipulating and commenting the information content in turns. However, accomplishing navigation task vary across different representations and display medium. Navigation in the VR model was accomplished through the collective effort of team members. The meeting facilitator (i. e., the technical operator), navigated the VR model via keyboard and mouse input controls while other team members assisted the process by contributing to what objects to observe and locations to visit. Collaborative realisation of navigation in the VR model was evident in the team's execution of the task. The reason being that successful accomplishment of navigation in the team dwell on technical operation (i.e., utilisation of navigation tools) and contributions of team members in accessing relevant aspects of the design. By contrast, navigation in the 3D CAD rendering SmartScreen medium display and mobile technologies was accomplished solely by the navigator through view set up techniques (zooming, rotating, orbiting and panning) via keyboard and mouse control as well as hand input control. Accordingly, the method and technique of accomplishing navigation task, which depended on both the navigation functionalities of the medium as well as the workflow of the team affect flow of the interaction process and participation of the team members during the meeting session.

Objective 5: Explore the interplay that exists between different types of interactions during the design meeting session.

The research findings suggest that digitally mediated design review is a fluid process involving intricately connected verbal and non-verbal actions and task, enabled by mobilisation of personal technologies and shared media to communicate and develop the design. The findings from this study reveal that instances of participants' actions and task are all intricately connected and do not lend themselves to a clean separation. The intertwined nature of interactions among the team became manifest as participants in the design team seamlessly switched between different verbal and non-verbal behaviours (descriptive, explanative and evaluative, viewing, gesturing, navigating) as well as different representations and medium to accomplish a task during the meeting session. As range of behaviours overlapped to accomplish a task, successful transition between different types of actions, tasks and media assemblage is key to richer interaction during the meeting session.

Finally, the research findings indicate that the digital space is primarily characterised by mobilisation of personal technologies, customisation of user experiences and enactment of use of display medium and information representation as well as user-driven tasks to support their actions and accomplishment of task. These activities ensure that the actions and tasks of the participants are richly supported during the meeting session. The next section explains the significance of these findings in relation to knowledge and practice.

6.3 Research contributions

This research contributes to the current literature on team interactions mediated by technologies in the digital space within the architectural design meeting context. The research on team interactions mediated by technologies mainly tend to approach the digital space as fixed technological set-up whereby the design team create, share and use digital information to support their actions and activities during the meeting session. Besides, prior research incline to concentrate on either the media-specific features or media use, and also the information representation and the display medium as single entity to understand the nature of actions and activities that unfold in the digital space. However, very little published literature specifically explores the nature of team interactions supported by technologies from the fluid perspective of the digital space, and distinguishing the media's constituent parts (i.e., the information representation and the display medium) where their specific features and situated use in practice tends to introduce implications into how interactions unfold in the digital space. These contributions are discussed below.

6.3.1 Theoretical contribution

This research provides team interaction process framework, mediated interaction approach and use of technology-in-practice lens being applied to understand the nature of interactions among team members and with technologies (i.e., medium and representation) in the digital space within the context of architectural design meetings. The study defined the digital space as open and fluid where participants mobilise range of technologies, both personal and shared, and customise their experiences to mediate the accomplishment of task during the meeting session. With this conceptualisation, the study becomes useful in expanding our understanding of how flexible systems are mobilised, appropriated, customised as well as incorporated into existing technological set-ups to mediate actions and tasks of participants in the team's workflows. This knowledge contributes to the existing mediated design team interaction literature by informing conceptualisation of the role of personal technologies in mediating actions and activities of the design team during design meetings. Circumstances with which specific medium and information representation support or disrupt flow of interactions in relation to mobilisation of personal technologies is the main contribution that this study offers to the current body of knowledge.

The research findings draw attention to the importance of decoupling the medium from the representation in understanding the unique roles they play in mediating the actions and activities of the design team. This stems from the fact that each aspect of the media is configured differently in terms of how content of the design information is revealed and the approach to engage and interact with it. Hence, each account differently in terms of how the team interact with content of the design and among themselves over the course of the meeting. Besides, the findings highlight the intertwined nature of the different types of interactions among the team members and with technologies in relation to specific features of the display medium and the information representation as participants accomplish design tasks.

Further, this thesis argued that the dynamic exchanges that characterise nature of interactions ensued in the heterogenous and fluid digitally mediated design review process are underexplored within the digitally mediated design team interaction literature. Existing studies tend to present either the frequency and duration of occurrences of actions among the team members and with technologies at the larger group stage by considering ensuing exchanges as purely collaborative engagement, that do not discuss individual and sub-group breakaways and the role they play in enriching the exchanges unfolding around the evolving design (e.g. Liston, 2009; Tory et al., 2008).

Hence, this thesis contributes to the mediated team interaction literature by presenting narratives of mediated team interaction that specifically discuss the relevance of informal activities of individuals and sub-groups on the interaction process. The video data of the various design review meeting sessions observed within this thesis established that without the incorporation of individual and sub-group activities to augment the larger group activities, the needed information required to aid participants' experiences of the design and enrich discussions to modify the existing design decisions would be inadequate to mediate the actions of the team (see Sections 4.5.1 and 4.5.3). The quest to develop extensive experience and interactions, coupled with shortcomings in terms of content of the existing information and the display medium in allowing flexibility to transfer of informal information to a shared information for better appreciation of the design. This disrupted the collaborative engagement of the team members in reviewing and modifying the existing design content, and the flow of exchanges around the design.

Although the incorporation of information representations and display medium are extensively published within academic and industry literature (e.g. Liston, 2009; Liu, 2017; Fard, 2006), these mainly appear to present the effect of embedded properties of digital media in isolation of the complex interaction process, where emphasis shifts to the team members within context of their activities. Besides, the approaches employed to explore nuances of participants' behaviours unfolding around the design information are generally narrowed and deterministic in nature, focusing on either effect of the embedded properties of the media or how they are used to shape the actions and activities of the team.

This thesis argued that these approaches emphasize high level interactions ensuing in the team and give more prominence of technological properties of the digital media in exchanges of the team that is being explored (2.8), hence a micro-level approach to exploring the range of actions situated in the social, technological and material context of their emergence may prove more useful in unveiling all essential details that characterise nature of mediated interactions that are discussed within technology use in practice in the design and construction literature (Orlikowski, 2000; also see Section 2.8).

This thesis contributes to this literature by presenting examples of video-recordings of participants' interactions supported by digital representations and display medium in series of design review meeting sessions that indicate that importance of focusing on the moment-to-moment actions of participants around the design and how specific features of the information representation and display medium are utilised to mediate the actions of the team. The analysis of the video data established how participants customised use of specific features of the media (information representation and display medium) to realise different tasks under different conditions. This knowledge contributes to the literature by adding a dimension of context to the use of digital media in supporting verbal and non-verbal actions of the design team, and also serves as an alternative approach to the mechanic view of information representation and display medium within some of the prior digital media utilisation studies. Importantly, it provides a new way of thinking about the role of digital media through exploration of knowledgeable actions of participants in their interactions around the design information.

6.3.2 Contribution to practice

The findings contribute to practice, specifically, planning for team interactions in terms of creating an enabling environment for effective mobilisation of participants' personal mobile technologies to support their actions and accomplishment of task, since findings of the research have highlighted the nature of actions and tasks driven by the experiences of the team members. The fluid nature of the digital space means that its users tend to spontaneously introduce their personal mobile technologies to either augment or compensate for the existing technological set-up of the digital space. This knowledge is expected to inform the meeting facilitators or design managers about the nature of participants' actions and tasks and relevant technologies required to be mobilised to support their tasks and also disruptions emerging and circumstances of their emergence so as to accommodate those limitations in their planning and assemblage of media with relevant features to enrich flow of interactions and participation of team members thereby enriching the interaction process.

The results have also provided insight into circumstances contributing to a particular medium or information representation being supportive or disruptive to the team's workflows. This information serves as arsenal of knowledge with which practitioners could rely on to inform their decisions and approaches to planning effective interactions in design meetings thereby enriching design decisions arrived at.

Although this study focuses on design meetings in architectural design practice, the findings may well have a bearing on team meetings in other design disciplines supported by media in the digital space. Again, project teams in other phases of the construction project may benefit from this knowledge for planning of effective team interactions supported by digital spaces.

This analysis and results deliver several messages. First, the digital space is fluid in nature, allowing mobilisation of personal technologies and customisation of user-experiences to support actions and tasks of the design team. Second, the representation of design information and the display medium are both unique in their own rights to provide different support to the actions and activities that unfold in the digital space. Third, the role of the media in enabling the actions and activities of participants are well acknowledged when the media-specific features, their enactment of use and the moment-to-moment use are investigated together. Fourth, participants' desire of mobilising their personal technologies to facilitate specific user-driven experiences and tasks ought to be supported with relevant mechanisms to blend with existing shared displays for richer interaction. Finally, rich interplay exists between different types of communication instances and non-verbal interactions to accomplish actions and tasks of participants during the meeting session.

By aligning the salient features of the information representation and display medium to the emergence and accomplishment of verbal and non-verbal actions of the design team and analysing the interplays existing between them, this method contributes to industry understanding of digitally mediated interaction as an iterative process of action reconfiguration. The expected benefits of doing so are to enrich selection of appropriate digital media to facilitate the actions of the team, reduce bottlenecks with the use of specific features of the media and increase participation of team members throughout the interaction process.

This thesis also makes an empirical contribution to designers of digital technologies by providing a detailed account of the fluid digitally mediated design review process, the key actions that unfold and how they affect use of specific features of the media, especially features that support or disrupt the actions of the team, and proposed recommendations that digital technology developers can use to inform the design of next generation digital technologies.

6.4 Research implications

The findings of the research have several implications in the various aspects of team interactions supported by technologies in the digital which includes theoretical and practical implications as well as methodological and design issues. These implications are discussed in the sections below:

6.4.1 Theoretical implications

Despite limitations of the findings (see Section 1.5), the findings may have several interesting theoretical implications. First, the findings have contributed to our understanding of the fluid and complex nature of mediated-team interactions in design meetings within the digital space in architectural design practice by offering comprehensive insight into nature of interactions that unfold in the digital space and activities that lead to richer interactions during the design meeting session. The need for holistic consideration of mobilisation of personal technologies, customisation of media with specific features, flexibility in enactment of use of the media as well as separation of the medium and the representation is emphasised.

Second, when compared to literature on role of media to support team interactions (e.g., Liston, 2009; Tory et al., 2008), there is significant emphasis of the: i) unique role of the information representation in mediating the actions and tasks of participants in terms of nature and types of actions employed and how the work flows in the team compared to a monolithic view of the media together where the unique contributions of each of the entities intervening the actions and activities of participants are undefined, hence not adequately configured to enrich the interactions of the team. Approaching each constituent part of media as potential means to support activities of the team enrich the understanding of the effectiveness and extent of supporting specific aspect of the team's actions. The complementary role of each of the constituents of the media, i.e., the medium and the information representation in supporting the activities of team members, and how their configuration and enactment affect the user-experience are clearly defined (see Figure 6.1).

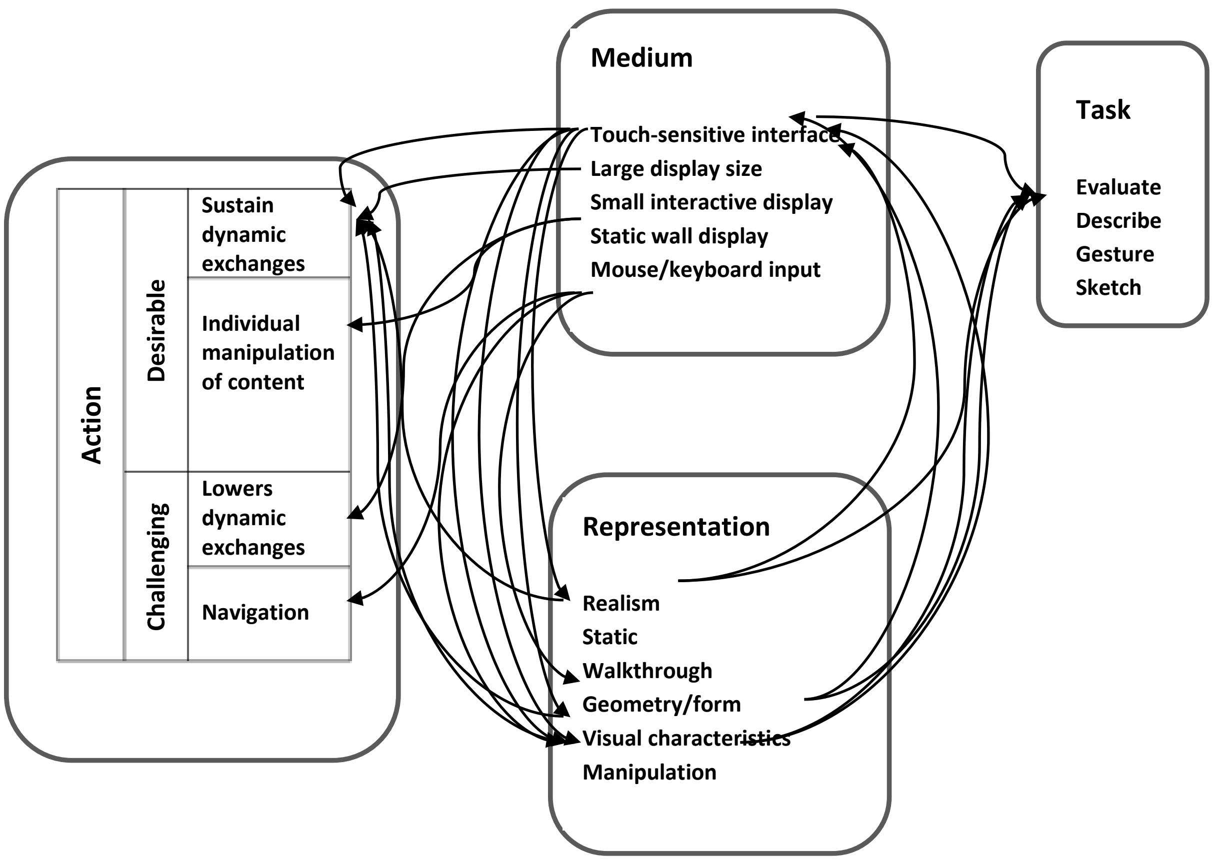


Figure 6.1 Complementary role of the information representation and display medium

The findings in this study has contributed to extending our understanding into specific roles each constituent aspect of the media employed to support the action and activities of the participants in the digital space by revealing that each component is distinct in terms of how they support emergence and accomplishment of actions and tasks, both the social interactions among the team members and their engagement with the information content; ii) introduce flexibility in accommodating both permanent and temporal or personal and public technologies as well as user-driven tasks to enrich the interactions, both among the team members, the information representation and the medium in the team's workflows because of the fluid and changing nature of the digital space and limitations in the existing set-up of the digital space. To respond to changes in participants' actions and tasks as well as technological mobilisation and capture all the essential tasks (fixed and ad-hoc) and user-driven experiences in terms of appropriation and customisation of the use of the medium and the representation in supporting the task, so that they can be combined to enrich the interactions of the design team, both with the media and among themselves within the mediated design review context. Third, the concept of the digital space and use of media has been modified to accommodate the fluid nature of the digital space and the essential characteristics of the medium of display and information representation. Contrary to prior literature (Liston, 2009; Tory et al., 2008), where the digital space has been approached as a fixed or mechanistic entity enabling creation, management and use of digital information. In contrast, the digital space was characterised with activities such as mobilisation of personal technologies, customisation of user-experiences as well as enactment and appropriation of the existing technological set-up and reconfiguration of its use to ensure effective and rich interactions among the team members.

Finally, the concept of media use has been modified to accommodate the media-specific features in mediating the actions and accomplishment of participants' task in the digital space. The combination of the essential dimensions of features and nature of the media in relation to both the medium and the representation in effectively supporting participants' actions and activities- that is synthesizing both media features as well as its situated use is critical to yielding useful insight into its contribution in mediating interactions of participants.

6.4.2 Implications to practice

Parts of the thesis could be viewed as a potentially important tool and guidance for those trying to plan and promote richer interactions among participants in the design team. It is posited that the research findings and recommendations could specifically be used by:

- Digital technology outfit of the design firm as well as the management to guide investment decisions on deploying new technologies with richer capabilities to support user-driven actions and tasks of participants during design review meeting sessions. This is premise on the fact that findings of the study have revealed the salient features of both the medium and the information representation which are richly utilised to support discussions of the design team during the meeting session. Again, the results of the study have highlighted inherent limitations of the current technological set-up of the digital space in relation to facilitating the transfer of personal or private information to a shared information as well as supporting usage of personal technologies in augmenting existing visualisation technologies or mediating the participants' activities.
- Architectural designers and project managers charged with the responsibility of planning and organising design meetings rich in interactions among the team members

and with technologies assembled to support actions and activities of participants could be informed by outcomes of the study about nature of actions and tasks embarked upon by the team members as well as the salient features of relevant technologies that needs to be mobilised to support the actions and tasks of the design team.

- Besides, architectural designers engaged in collaborative design activities could rely on knowledge of the iterative processes of groupwork, sub-group and individual activities that characterise the verbal and non-verbal actions ensuing in the design review meeting process. The premise being that variation exists in how the digital space is configured to allow for incorporation of appropriate display medium required to enhance participants' experiences and interactions of design information. By this awareness, architectural designers engaged in collaborative design review tasks would be better informed about the need to accommodate all the nuances of behaviours, which include informal individual and sub-group activities as well as the formal group activities. This flexibility would give participants ample opportunity to extensively engage with relevant content of the design thereby enabling them to modify their experiences and provide meaningful contributions to enrich decisions on the evolving design.

6.4.3 Methodological implications

The key implications for informing method of approaching investigation of team interactions supported by media in the digital space are two-fold.

- First, as actions and activities are fluid in nature, switching between primary and ad-hoc activities and tasks to support their interactions, there is a need for researchers to employ robust analytic approaches capable of capturing all nuances of participants' tasks and user-driven experiences which adapt to the fluid nature of the digital space in supporting participants' varying experiences and task while interacting to communicate and develop the evolving design. Since the digital space is not fixed, rather, it is a fluid environment where mobilisation and use of media as well as emergence and accomplishment of user-driven experiences and tasks emanate from local context with unpredictable encounters between the participants in the design and with both the medium and the representation at the micro-level of interaction. The challenge for researchers, in particular, is to develop analytic model which account for the changing nature of user-driven experiences and tasks in appropriating and customising the medium and information representation in their exchanges to accomplish a task. The investigative and analytic approach should move away from the current emphasis on coding and quantifying strategies which are akin to higher level fixed-support interactions of team members, to a more flexible approach which accounts for the unpredictable, fine-grained moment-to-moment actions and activities which emerge over the course of the interaction to capture the context-specific interactions.

- Second, within this fine-grained open analysis, the unique role of the medium as well as the representation, both in supporting or disrupting interactions among the team members and with technologies assembled to facilitate the task needs to be well acknowledged, thereby shaping understanding of nature of interactions that unfold in design meetings within the digital space, hence expanding the frontiers of knowledge within the domain of the mediated interaction literature. A remedy for this, for example, is analytic approach to support capturing of fine-grained moment-to-moment social interactions and mobilisation of technologies, both personal and public within the social and technological context of actions and tasks of the team members with the architectural design review context.

6.4.4 Implications for media designers

The implications of the research findings for designers of digital spaces and media are discussed as follows:

- First, designers could consider designing digital spaces flexible enough to accommodate all user-driven experiences and behaviours, both routine and ad-hoc as embarked by participants in the interaction process. Besides, the digital space should be equipped with relevant facilities to support participants' activities such as mobilisation of personal technologies and appropriation of the digital space to enable users customise their experiences and embark on specific ad-hoc task as may be required in their workflows. Further, the digital space maybe furnished with mechanisms to facilitate smooth transfer of design information between personal technologies and public displays, and also support combination of mix media as suggested by Fard et al. (2006) and Tory et al. (2008). By this arrangement, individuals desiring to obtain personal version of the information on public displays on their personal mobile devices for better control over manipulating specific information content could do so without a struggle. Similarly, the design team could collaboratively obtain access to new information displayed on individuals' personal technologies. This would enable participants obtain easy access to new information and interpret them to support group discussions, while at the same time taking control over manipulation of design content via the touch-sensitive interface of their mobile devices for richer interactions, both with the information content and among the team members.

- Second, media designers, both in the area of display medium and information representation, should consider equipping the digital media with user-friendly enhanced functionalities to support navigation, annotation/mark-up, viewing, gesturing, sketching, evaluating, describing and explanation tasks as well as their fluid transitioning in the team's workflows. These provisions would enable the participants to fluidly switch between different actions and perform interrelated tasks while communicating to understand the design and transform its content. Finally, future media designers need to assess relevance of the media in terms of switching and combining as well as richer engagement while accomplishing the team's tasks.

6.5 Suggestions for future research

The findings and limitations of this study give rise to a series of recommendations for future research:

- It would be imperative for future research to broaden the applicability of the results by conducting multiple case study and increasing coverage of design meetings observed. By this, more instances of participants' interactions would be observed to meaningfully enrich quality of research outcome produced, hence informing generalisation to the theoretical understanding of team interactions supported by media in the digital space during design meeting sessions.

- One of the key findings of the study has been increasing utilisation of personal/informal mobile devices with or without formal devices or shared displays to support interactions of participants in the design team. A thorough, more focused study of mediating personal mobile devices and public displays while supporting actions of team members in the digital space could produce interesting findings that account more for how use of formal and informal devices are effectively mediated to facilitate interactions of the team;
- As the research focuses on design professionals within a single architectural design practice, future work could consider designer-client interactions around array of media in the digital space to provide further dimension on how professionals and non-professionals cope with the unstable and heterogenous digital space while interacting to communicate and transform the evolving design.
- This thesis focuses on understanding team interactions in the digital space in relation to use of media without recourse to other important context issues during the meeting session. Nevertheless, it is possible that other context issues such as task/project characteristics as well as background of the team members could inform the emergence and accomplishment of verbal and non-verbal actions of the team members and how media within the digital space were effectively utilised to facilitate the interactions of the design team during the meeting session. Future research on the nature and role of task/project characteristics and background of the participants might yield greater insight into issues enriching interaction within the perspective of context.

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Appendix A: Publications

Conference Paper:

Ofori-Darko, J., Nikolic, D. and Harty, C. (2018) *Team interactions in digitally – mediated design meetings.* In: 35th CIBW78 2018 Conference: IT in Design, Construction, and Management, October 1-3, 2018, Chicago, Illinois, United States, pp 247-254.

Academic Presentations:

Ofori-Darko, J (2018) Team interactions in digitally mediated meetings. Annual SBE PhD Conference Proceedings, 18 June, University of Reading.

Ofori-Darko, J (2017) Emergence of design team communication in digitally mediated design review meetings. Annual SBE PhD Conference Proceedings, 26 June, University of Reading.

Academic Poster:

Ofori-Darko, J (2016). Exploring interaction pattern of designers in BIM-enabled collaborative designing. Annual SBE PhD Conference Proceedings. University of Reading.

Appendix B: Consent form

School of the Built Environment

University of Reading

Whiteknights

Reading

RG6 6AW

Project title: Team interactions in digitally mediated design meetings

Information Sheet

My name is Jacob Ofori-Darko and I am a PhD student in Construction Management, School of the Built Environment at the University of Reading. I am carrying out research on design team interactions while using media. The goal is to understand actions and activities that emerge during collaborative design tasks, and the salient features of the media that affect these interactions in design team meetings. The benefits of this study include obtaining insight into how specific features of the media may affect team members' interactions in the design process for specific collaborative tasks.

By agreeing to participate in this study, you will be asked for permission to video record the design meeting(s) you are participating in. The video recordings will be transcribed to analyse the data on verbal and non-verbal interactions among the team members, and the use of media and project information during the meeting session. All identifiable project information such as project name, size, budget, relationships, roles or responsibilities will be removed from the transcribed data. Portions of the video may be used for academic presentations and publications, either as recorded video, audio, or as extracted still images. These will not include any identifying or confidential information. Copies of the video transcript and any video or audio recordings will be available on request and any changes which you ask for will be made.

Your participation in the study is entirely voluntary. You can withdraw from the study at any time. Your name and all project or organization identifying information will be removed from the written transcript. My supervisor and I will be the only people who will have access to this data. The data will be kept securely and destroyed when the study has ended, which will be a maximum of 3 years from the completion of the research. The data will be used for academic purposes only. Copies of any outputs, such as articles or presentation slides, will be available on request.

This project has been subject to ethical review, according to the procedures specified by the University Research Ethics Committee, and has been given a favourable ethical opinion for conduct. For any questions or concerns, please do not hesitate to contact me at j.ofori-darko@pgr.reading.ac.uk (tel:), or my supervisor, Dr. Dragana Nikolic at: d.nikolic@reading.ac.uk (tel:

Signed: **..** Date: ....

Consent Form

In line with ensuring adherence to research ethic requirements and best practice in video data collection, handling and protection, the following statements seeking your consent have been developed. By signing the form, you acknowledge that you have read and understood the information provided.

1. I have read and had explained to me by Jacob Ofori-Darko the Information Sheet relating to this project and any questions have been answered to my satisfaction.
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason.
3. I understand that my personal information will remain confidential to the researcher and his supervisor at the University of Reading, unless my explicit consent is given.
4. I understand that my organisation will not be identified either directly or indirectly without my consent.
5. I agree to the arrangements described in the Information Sheet in so far as they relate to my participation.

Please complete the section below:

Participant Name (Please Print) Signature Date

Investigator Name Signature Date

As part of this research, we will be making audio/video recordings. Please place your initials in front of the statements with which you agree:

- _____ I give consent to the research team to use audio/video data for use in this study.
- _____ I give permission for the researchers to use images extracted from the video recordings for conference presentations or scientific publication in accordance to confidentiality agreements.