IT-Integrated Design Collaboration Engagement Model for Interface Innovations

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Abstract: - Due to the advent of computer-based technologies, data sharing and communication in collaborative design environments have significantly improved. However, current systems' interfaces do not support mutual understanding among professional design team members. This only contributes to increasing levels of miscommunication and lesser understanding among design professionals in IT-integrated design collaboration processes. The purpose of this paper is to understand and nurture engagement of design professionals within the building and construction sectors to the computing system interfaces, so they will actively participate in IT-integrated design collaborations. This study utilizes Grounded Theory Methodology to explicate our understanding about engaging design professionals. While *control* and *feedback* are common parameters of engagement in prior models, the study found the need to add *functionality* to engage design professionals in IT-integrated collaborative interfaces. These parameters would enable design professionals to mitigate process rigidity caused by inefficient knowledge allocation, knowledge retrieval and decision-making control. Additionally, they would also mitigate against inadequate user performance, which resulted in operational deficiency. Thus, the present IT-integrated design collaboration engagement model is expected to increase communication and collaboration among design professionals. By facilitating user-friendlier interfaces, they will be motivated to adopt collaborative technologies thereby encouraging them to develop their proficiencies for working in global collaborative projects.

Keyword: - Engagement Model, Grounded Theory, IT-Integrated Design Collaboration, Human Computer Interaction, Human Computer Interface.

1 Introduction

Design collaboration is an activity that requires the participation of project team members to organize design tasks and to share experiences [1, 2]. This activity is performed by organizing design tasks and resources, as well as sharing expertise, ideas and design information among design team members. Nowadays, the increase in internet-based and collaborative technologies has created a promising approach to non-collocated or distributed design collaboration processes. Consequently, design team members have become more internationally active due to globalization and increased networking capabilities between industrial partners across the globe [2]. In addition, the advances in technologies, such as PHIDIAS hypermedia system [3, 4], Building Information Modeling [5] and Virtual Prototyping [6] makes it possible for professional design team members to collaborate through an internet or intranet server and communicate with each other through collaborative tools and technologies beyond physical boundaries and time zones. However, this has potentially increased miscommunication among design team members from the system use and interface design. This is due to the fact that the interpretation of data produces many semantic ambiguities [7].

Eventhough the revolution from design collaboration to IT-integrated collaborative design has been picking up fast, many design team members are still not familiar with collaborating using IT-supported technologies. Currently, in the design collaboration environment, project team members are more used to collaborations based on conventional methods of communication, such as face-to-face meetings, exchange of paper documents in the form of technical drawings, and paper-based site instruction specifications [8]. Indeed, they are yet to fully utilize computer-based technologies while communicating with each other. This is even more prevalent in the early stages of the design collaboration process, where the spotlight is on managing and sharing design information among design team members rather than focusing on a way of improving interaction among collaborating members [1].

To remain competitive in non-collocated design collaboration processes, the building industries should improve the communication and collaboration among design team members. One approach is to understand the interaction of professionals with computing systems and develop interfaces that engage them to IT-integrated design collaboration process. This paper aims to integrate human or user aspects into system development. Thus, the resulting systems are developed based on design professionals' needs, as well as organizational needs. The purpose of this paper is to identify the human needs that will engage design team members to the IT-integrated design collaboration process. To effectively engage professionals, the grounded theory methodology enables the researchers to discover a theory which is suited to design team members who collaborate in IT-integrated design collaboration processes.

This paper starts with a brief introduction and an overview of the background problem. After the literature survey, we present the methodology, the results and analyses from field work. The paper will then present the development of the proposed model for engaging design team members in the IT-integrated collaboration process before discussing the validated findings.

2 HCI in Design Collaboration Process

This paper focuses on engaging design team members in IT-integrated design collaborations using the concepts of Human Computer Interaction (HCI). HCI is defined as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" [9]. Human Computer Interface is a well-known concept in HCI research. Sheppard and Rouff [10] define human computer interface as the point of contact that enable end users to communicate with computer applications. This interactive communication between users and computerized applications raise the "usability" issues. Chou and Hsiao [11] defined it as the extent to which the user and the system can communicate effectively and without misunderstandings arising from the interface. Their study presented the effects of age on the usability of computer systems based on a project that was executed to encourage unemployed adults, particularly middle-aged workers, to learn elementary computer skills, enabling them to operate computers. A more user-friendly computer interface was therefore required. For instance, the usability analysis showed that the middle-aged learners had more similar user characteristics in keyboard or monitor usage, application preference, software use difficulty, and also views on present interface design. Previous empirical studies thus help to discern the elements required to satisfy designers in the collaborative process. However, usability is not the only human factor that should be considered when designing an interactive human computer interface. It is one of the human factors under the human cognitive dimension in HCI. Even though cognitive psychology plays an important role in HCI, the understanding of humans entails more than just cognitive aspects. Therefore, this study will emphasize the entire human psychological aspects in a design collaboration process which incorporates collaborative technologies.

The application domain of this study focuses on design collaboration process. The design collaboration process among design team members is accomplished by sharing and organizing design ideas, resources, and expertise for an agreed design task [12]. Many studies have indicated various efforts towards facilitating collaboration using IT/ICT in design collaboration and engineering [13, 14, 15, 16, and 17]. In addition, there has been a large number of software applications developed for the collaborative product environment [18] and communication in a distributed collaborative environment [19, 20]. Similarly, PourRahimian and Ibrahim [21] propose utilizing collaboration in real time using virtual reality to improve communication in geographically dispersed locations in developing countries. In particular, they illustrated the usefulness of 3D sketching in the CAVE collaborative design environment [21]. Accordingly, Haymaker et al. [22] developed a 'Filter Mediated Design' in which the mechanism was augmented using agents for achieving coherence and innovation in remote design collaborations. Similarly, Larsson [23] presented an observational study, where collaborative design team members would negotiate common ground in collocated collaborations effectively, subtly, fluently, and effortlessly; such as negotiating by telling stories and using indexical representation. However, in those studies, the technologies either decreased the creativity level of the designers or indicative of a lack of natural communication way for global collaborations. It is in this view that, this paper attempts to evaluate how design researcher could simplify interface interaction in IT-integrated design collaboration while maintaining the creativity levels and attraction of experts through natural way of computer-supported communication. Furthermore, Erickson and Kellogg [24] designed 'Babble' by making participants and their activities visible to one another in a collaborative network. Similarly, Hailpern et al. [25] facilitated the creative design process by providing re-interpretation and reflection-on-action capabilities by developing a novel system that satisfies the requirement of real time collocated design collaboration. Our study posits that existing advanced IT-integrated collaboration technologies in design collaborations show weaknesses in supporting human understanding thus they are frustrating to use. Therefore, this paper would like to recommend designing systems' interfaces for professional design team members to retain professionals' attention and interest and reduce their distraction while they interact with the interfaces in IT-integrated design collaboration process.

Moreover, "engagement" is a term that appears in human computer interface research. O'Brien and Tom [26] defined engagement as a dynamic process, which reflects a two-way interaction between the user and system or interface changes. The application of human computer interface and integration of HCI in many collaborative domain studies reveals that the traditional standalone and distributed CAD are system-centered rather than human-centered and they are not engaging to the users. Additionally, they do not allow designers to follow their own design paths. On this subject, Ye et al. [27] stated that designers have not been fully satisfied with the design functions and UIs (the mouse/keyboard and 2D display interface) that most commercial CAD systems have provided. Examples include having no freeform in shape creation or no allowance for 3D freehand sketching type usage. Thus, their study developed an innovative conceptual design system called LUCID (Loughborough University Conceptual Interactive Design) system. It was designed to improve the interaction between designers using Virtual Reality technology and it presented a human computer interface over the conventional CAD systems. Similarly, Sener and Wormald [28] enhanced CAD to fit better to industrial designers' needs for conceptual form creation in virtual workshops and intelligent environments using smart material, haptic holograph representation and automated 2D-to-3D translation. Moreover, He and Han [29] presented a descriptive, prescriptive and computer-based model of human-human interaction in collaborative design to support human-human interaction. The aforementioned studies have presented the importance of human factors in current CAD or collaborative CAD systems. However, they were all applied in the product design manufacturing process. Due to the arguments presented above, this paper proposes the integration of HCI context in the design collaboration process and will reveal the critical human factors that engage design team members to the collaborative system interfaces in the IT-integrated design collaboration process.

3 Engagement in Design Collaboration

This study has developed a theoretical proposition through the analysis of literature. In order to identify which parameters of engagement were the most dominant in IT-integrated design collaboration processes, the study moved towards the theories of adapting technology. Accordingly, by analyzing related theories, the study is directed to the identification of appropriate models for user behavior in accepting IT. These models are Technology Acceptance Model (TAM) [30], Theory of Planned Behavior (TPB) [31] and Unified Theory of Acceptance and Use of Technology (UTAUT) [32]. The main constructs in TAM are defined as perceived usefulness and perceived ease-of-use while in TPB are defined as perceived behavioral control and motivation. Consequently, the main constructs in UTAUT are defined as performance expectancy, effort expectancy, social influence and facilitating condition. In addition, the studies on engagement present that engagement consists of many parameters. These parameters consist of user control [33], focused attention-relevance to users' tasks [34, 35, 36], novelty [34, 35, 36], aesthetic and affective appeal [34, 35], felt involvement [34], motivation [34, 37], challenge [38, 39] and feedback [38].

As a result, we combined 1) obtained constructs from various models of technology adaptation, along with 2) the parameters of engagement from the previous studies, and 3) studies of IT-integrated design collaboration in order to determine the most dominant engagement parameters in IT-integrated design collaboration processes. From then, the study posited that enriching design team members with *feedback*, *functionality* and *control* will make professionals more comfortable and motivated to communicate and collaborate using IT-integrated collaborative technologies in a building design process.

For the purpose of this study, we define feedback as the processed information such as design output that is transferred to or from other design team members to update or improve their actions. In this view, we follow Ibrahim [40] and Ibrahim et al. [41] who defined this movement of processes information as knowledge allocation or knowledge retrieval communication. Therefore, in this study, the research refers to *feedback* as the knowledge, which is allocated to appropriate design team members and the knowledge that is retrieved from other design team members to be used or improved on by others. Moreover, our study refers to TAM's, which equate functionality as the perceived usefulness of a technology [42]. Davis defines perceived usefulness as "the degree to which a person believes that using a particular system would enhance his or her job performance". Similarly, Amoako-Gyampah [43] indicates that the perceived usefulness can be measured by identifying how flexible the technology and how the technology would increase a user's performance, productivity or effectiveness. As a result, we define *functionality* as the degree of user performance with the computing system and the degree of technological flexibility afforded to the user.

The TPB Model refers to perceived behavioral control as "an individual's perceived ease or difficulty of performing the particular behavior" [44]. It has two aspects. First, is self-efficacy [45] and the second is controllability [46]. Bandura [45] describes self-efficacy as the confidence a person feels about being able to perform or not to perform the behavior. On the other hand, Francis et al. [46] describe controllability as how much a person has jurisdiction over his or her own interaction behavior toward a technology. In contrast to self-efficacy, Francis et al. identifies controllability to govern factors beyond users' belief and confidence to determine their interactive behavior. In this study, we posit that design team members will have low control in decision making if the system often malfunctions. Consequently, system malfunction is a factor beyond their belief and confidence to maintain control in an IT-integrated design collaboration. Hence, we proposed *controllability* as the degree of jurisdiction or power allowed by technology on the interactive behavior of the professionals.

4 Grounded Theory Research Methodology

The process of engaging design team members in IT-integrated design collaboration process is applied using Grounded Theory Methodology (GTM). Glaser and Strauss [47] and Strauss and Corbin [48] defined GTM as a process by which a researcher generates theory that is grounded in data. It was selected because the study of design collaboration and the behavior of design team members in the IT-integrated design collaboration environment required the researchers to evaluate whether there is sufficient complexity to generate a theory that could be of potential value to building projects. This is supported by Glaser and Strauss [47] who established that grounded theory could generate a theory that is relevant, fits, and modifiable to the 'supposed user' and emphasizes on generating rather than verifying theory. Furthermore, Taylor and Bogdan [49] argued that GTM is a method for discovering theories, concepts or proposition directly from data rather than existing theoretical frameworks, research or a priori assumptions. In this research, the resulting theory is directly based on the raw data collected from design team members, who have significant experience in building projects. Details of their collaboration and communication habits were expected to form the data, and as such, GTM was deemed the most suitable method for this research study.

In the following section, we describe the detail of how GTM method is used. According to Pandit [50], GTM should have five main analytical phases: research design, data collection, data ordering, data analysis and literature comparison. The application of these phases in the design collaboration process is briefly described below. The data source was a homogenous group of Malaysian building professionals who had experience collaborating in design collaboration processes. The initial data source was collected through interviews guided by an approved interview protocol as was commonly used by most grounded theory studies [51]. The first author conducted interviews, took interview notes and transcribed them. These data was then recorded as memos.

The interview protocol used unstructured and open-ended approach for obtaining information from professional design team members. The interview protocol composed of 20 descriptive questions as recommended by [52] aimed at obtaining opinions of design professionals regarding design communication and factors that would motivate them towards IT-integrated design collaborations. The respondents for this study are ten professional design team members who have experienced in building projects' design collaboration. They were selected using theoretical sampling. According to Strauss and Corbin [48], theoretical sampling is "sampling on the basis of emerging concepts". Theoretical sampling is a cumulative process [48]. It implies that theories are the result of different data which the participants provided. The collected data was later transcribed to understand the opinion of these professionals regarding factors that would motivate them to engage in IT-integrated design collaboration processes.

The above procedure involved iterative analytical process throughout the data collection period where the first author had to move back and forth to find, compare and validate the concepts, categories of the phenomena she had analyzed [53]. For the purpose of this study, ten distinct levels in the theoretical sampling methods were completed. Each level had corresponded to one constant comparative analysis—where the categories emerged trough the process of comparing data until adding new data does not generate a new category. The levels were indicated as CCA1, CCA 2…CCA10 as per indicated in Section 5. After the emerging data was collected, they were then further analyzed. After gaining insight into the emerging categories, properties, or patterns; the further interviews were conducted to validate those concepts and categories until we reach the saturation point in the study.

4.1 Process of Data Analysis

The ensuring data analysis step is integrating all the identified categories for the development of an IT-integrated design collaboration engagement model for building professionals. Strauss and Corbin [48] defined data analysis coding as "the analytic process through which concepts are identified and dimensions are discovered in data". In data analysis, the three main coding strategies are substantive open coding, axial coding and selective coding. Open coding is the initial coding process in analyzing data. Glaser [54] defined open coding as the process of fracturing the data into analytic pieces which can be processed into a conceptual level. The objective of an open coding analysis is to conceptualize the data and generate a new set of categories. Initially, the collected data for this study was categorized into various groups and named accordingly. In open coding, it is very important to reach the point of theoretical saturation. According to Strauss and Corbin [48] theoretical saturation is "a matter of reaching the point in the research where collecting new data seems counterproductive; the 'new' that is uncovered does not add that much more to the explanation at this time".

On the other hand, the axial coding process aims to develop the main categories and their sub-categories. It puts together data in new ways by making connections between a category and sub-categories (not between discrete categories which will be performed in selective coding) [50]. The next step of a GTM analysis is selective coding. It involves integrating the above-emerged categories to form the theoretical framework (refer to Section 7) as recommended by Strauss and Corbin [55]. Thus, the resulting generated categories would be further refined, strengthened and elaborated through a series of analysis steps. Finally, they were interrelated to reveal the model of engaging professionals in IT-integrated design collaboration processes by using a coding paradigm, which Creswell [51] describes this coding paradigm to include a group of components including central phenomenon, the casual condition, strategies, context, intervening conditions, and consequences (refer to Section 7).

According to Creswell [51], a single category is first identified as the central phenomenon of interest. The central phenomenon is a central category about the phenomenon. Casual conditions are active variables and they are more to do with the most interesting causes or findings. They will lead to the development of a phenomenon. Similarly, context is the background variable that deals with less interesting findings. Accordingly, the action strategies are the responses that occur as a result of phenomenon. Then, the strategies or any action or interaction that has resulted from central phenomenon are determined. Finally, the consequences or the outcome of the strategies (either intended or unintended) for the defined phenomenon are determined.

We then linked the categories based on taxonomic analysis as suggested by Spradley [56]. Using the above rigorous approach, we had developed a sophisticated typology using the super-ordinate and subordinate categories with multiple levels of categories in developing the IT-integrated Design Collaboration engagement model, which is presented in Section 7.

5 Results of Substantive Open Coding

A total of 486 codes were generated as a result of conceptualizing data results. However, they were minimized by a final grouping and a continuous comparison analysis process to evaluate the similarities and differences between them. There were a total of 322 new concepts generated from these codes. The following examples present a sample of open coding by defining key points from a few select interviews. These specific examples indicate the incidents that were identified and given a code.

Portion of data collected from CCA7:
*"The factor that makes communication using technology **difficult to use** is the **limited usage** of the emailing system. One drawing can sometimes be **big** and require **big space**. Sometimes **many emails** come at once and I cannot **open** my email."*

Portion of data collected from CCA9:
*"Our **capacity** for email is very small. So sometimes when the file is very **large**, we **cannot send** it through our email."*

The above incidents were conceptualized as "*Limited space in emailing systems for accepting large drawings*".

Furthermore, the process of data conceptualization was performed based on domain analysis. In this regard, the semantic relationships between the generated concepts and codes are identified in Table 1. It illustrates how the initial coding process was performed and how it works in practice. To achieve this outcome, the first author re-read the collected transcriptions and memos more than 10 times in order to make sense of the data and break them down into manageable codes.

As shown in Table 1, a set of relative incidents were given codes in Column 1. One of the codes describes that professionals can hardly send the design output to others by fax because the file sizes are so big. Similarly, the second code describes that professionals cannot send the whole bundle of files using a fax machine. Likewise, the third code describes that even if the email system is downed, faxing is still an inconvenient method of sending design output to others. Therefore, this study has conceptualized these codes as "*Limitation of fax machines in receiving large file sizes*" (refer to Column 3).

The multiple levels of analysis were important for several reasons. Firstly, these analysis levels led to a more sophisticated understanding of design team members' engagement in IT-integrated design collaboration processes. Secondly, these levels facilitated the generalization of patterns across multiple design team members. Hence, new concepts and categories that could not be anticipated during individual analysis could emerge. Thirdly, identification of semantic relationships, differences and comparison among raw data sharpened the information obtained from individual professionals during different interview sessions. This consequently validated the emerged codes.

Table 1: A Small Portion of the Substantive Open Coding Process for Concept Generation and Identification of Semantic Relationships

Included Terms	Semantic Relationships	Cover Term
E: Reference 1 - "They hardly send it by fax because it is so big"	Is a result of	E-9-7. Limitation of fax machines in receiving large file sizes
E: Reference 2 - "With fax, you cannot send the whole bundle of files."	Is a cause of	
H: Reference 1 - "Fax is not really convenient even if the email system is down."	Is a result of	

Referring to Table 1, the semantic relationships of the code are revealed and they signify that professionals hardly send design outputs by fax because the file sizes are too big. This *is a result of* emerged concepts called "*Limitation of fax machines in receiving large file sizes".* Similarly, the code that describes how professionals cannot send the whole bundle of files via fax *is a cause of* the emerged concept called "*Limitation of fax machines in receiving large file sizes"*. Likewise, another code which describes that fax is not really convenient even if the email system is down *is a result of* the emerged concept called *"Limitation of fax machines in receiving large file sizes".*

The next step in substantive open coding is to categorize the group of concepts at a higher and more abstract level [55]. Examples to explain how the initial internal and external categories were developed and considered as a foundation for the next step are shown below. These examples indicate the final result of the generated categories based on the concept groupings. Table 2 gathered a fair amount of emerging concepts emphasizing factors that make it difficult for professionals to use IT/ICT in a non-collocated design collaboration process. We grouped and categorized them as "*Factors of human inconvenience from using technology*".

Table 2: Samples of Emerging Concepts Grouped as "Factors of human inconvenience from using technology"

Node ID	Emerged Concepts	Description
G-18-31.	Absence of understanding problems with the current system	Even though the current communication methods are faster for professionals, they are not sufficient for understanding problems. Therefore, the members still have to meet each other face-to-face.
G-18-29.	Deficiency of having powerful technological communication	The big problem in current non-collocated design collaborations is the lack of a powerful communication tool.
B-18-6.	Slow receipt of information as a coordination problem	One of the issues in current technologies is time. Sometimes, the communication technologies are too slow and professionals cannot get the information quickly.
B-19-8.	Network problem	Slow network is one of the problems. For example, professionals have lots of drawings but the network is very slow to transmit them.
B-19-9.	Lack of high technology knowledge	Professionals usually don't have the knowledge of IT/ICT.
B-21-10.	Deficiency in IT training	Professionals are not provided with the training to teach and transfer the knowledge of technological communication.
C-20-11.	Too much adaptation to old technology	The mindset of professionals is more towards collaborating with conventional methods, such as exchanging paper documents and face-to-face communication.
C-21-14.	Persisting lack of being comfortable in using technology	Architects are not comfortable with using technology because as an artist, the imagination flies or ideas come at the spur of the moment. So, the best current tool for them remains the pen and paper.
D-20-12.	Knowing technology means less privacy	Professionals feel that technology is a barrier to maintaining their privacy.
E-21-16.	Ill-prepared for technology acceptance	Professionals are not yet fully ready for the technology.
H-18-14.	Lack of enough intelligence on available technology	Professionals still believe that the computer is not fast enough or isn't capable of understanding as humans do.

5.1 Application of Theoretical Saturation and Memoing

In this section, a deep analysis on the emerged categories from the substantive open coding is carried out. Figure 1 presents the theoretical saturation level of the emerged categories using constant comparative analysis (CCA). The first CCA is referred to as CCA1 and generated 17 categories. CCA2 validated 13 prior internal categories and added 8 new internal categories. Hence, CCA2 has a total of 21 categories. This process is repeated in the next cycle for CCA3 until CCA10. In our study, we reached saturation point at CCA7 where there were no new internal categories generated. The following CCA8 to CCA10 then provided the validation for all the earlier categories we had generated in CCA1 to CCA7.

In addition to theoretical saturation, theoretical memoing was also performed to prove the theoretical completeness of the results. These memos were written immediately and continuously attached to respective categories during the earlier data collection. They provided a form of validation for the analysis process and coding incidents were they strengthened the generated categories. We presented two memos as examples.

Category name*: Inefficient knowledge allocation*
Corresponding memo: *As the researcher has noted, based on the interviewees' experiences, the emailing system should be confirmed by letter after the design outputs are sent. They should be posted by letter later on. In addition, design team members face the problem of sending out their design output, as the file size is very big.*

Category name: *Limited practices of ICT in knowledge allocation*
Corresponding memo: *As the researcher has noted, based on the interviewees' experiences*, email *is the only technology to transfer design output to other design team members. However, in the emailing system, the design team members are only given 100MB. This is one of the problems with current emailing systems. Design team members have to inform the server master to increase their email space allocation if they want to send or receive a higher capacity.*

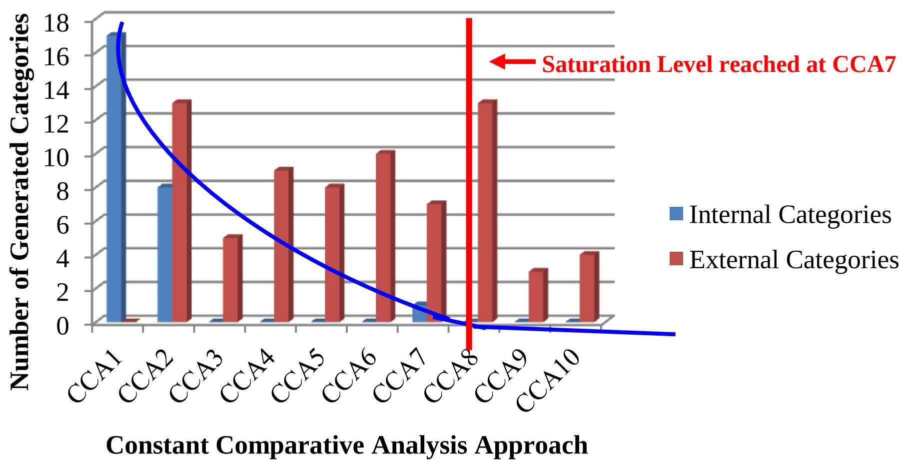


Fig.1. Result of Generated Internal and External Categories from a Constant Comparative Analysis Showing Saturation Point of Achievement

6 Results and Analysis of Substantive Axial Coding

After the categories were revealed in open coding, the properties of these categories were identified. It gives additional insight to integrate categories in selective coding, as well as to develop and conceptualize a more refined story line. Due to the large number of categories developed in this study, Figure 2 presents an example of the emerged properties for two categories related to the background problem.

For example, as presented in Figure 2, one of the emerged background categories was referred to as *"Factors of human inconvenience from using technology*" which is concerned with all the factors that cause professionals to feel uncomfortable to collaborate using IT/ICT. The properties are defined as follows.

- Firstly, the professionals are not provided with adequate collaborative technologies.
- The professionals need artificial intelligence technologies, however they have still not been provided with these technologies.
- Professionals usually encounter network problems, such as the server going down, regular internet disconnection and so on.
- Professionals do not have the knowledge of computing systems.
- Professionals are not provided with training sessions to improve their technical skills.
- Professionals are too used to the old methods and techniques of collaboration. Therefore, it is difficult for them to adopt the fast technical changes.
- Professionals are still not ready to accept and implement the new collaborating methods.
- Professionals believe that technology is a barrier to their privacy.

Similarly, another example of a category in Figure 2 is *"Manual/Physical coordination problem"*. This category is concerned with the factors that make communication in non-collocated design collaboration difficult when there is no technological utilization. The properties of this category are defined as follows.

- A large number of duties and tasks might be allocated to a single professional.
- Professionals might not really concern themselves with their allocated duties and tasks.
- The representative who is supposed to allocate design output might not have sufficient knowledge.
- In non-collocated collaborations, it is very difficult to reach other Architecture-Engineering-Construction (AEC) members.

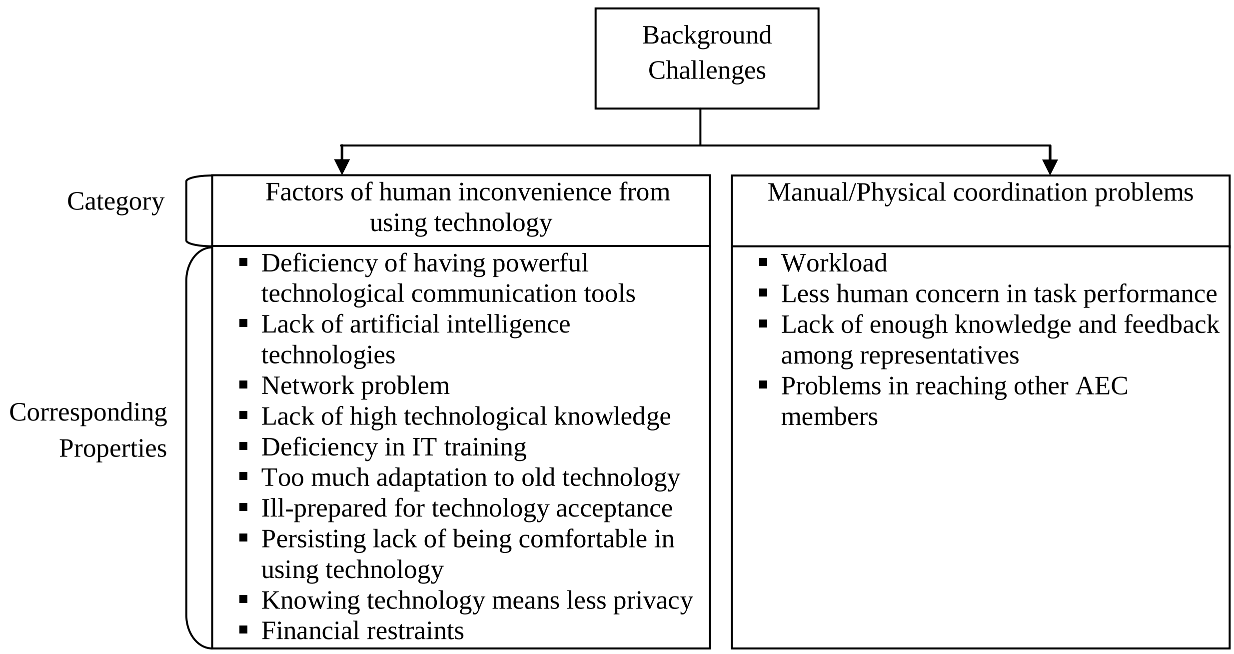


Fig.2. Sample of the Properties of Emerged Categories related to the Background Challenges

Furthermore, a classified descriptive table for the main groups of categories is presented in Table 3. The table has two columns: categories and corresponding literature support. The main purpose of this table is to determine whether the generated categories match the literature findings. For example, one of the emerged categories was referred to as *"Inefficient knowledge allocation"*. Coincidentally, Chiu [57] emphasizes the inefficiency of knowledge allocation in non-collocated collaborations, as it takes a long time for prepared data to be transmitted. This process would be even more time-consuming if the CAD drawings are not standardized and conversion is necessary. Table 3 presents example of 5 out of 26 emerging categories (refer Delavari and Ibrahim [58] for remaining 21 categories).

Table 3: Developing Key Themes from Constant Comparison Analysis Based on a Small Portion of Categories

Major Emerged Categories	Corresponding Literature Review
Inefficient knowledge allocation	Chiu [7] discusses lack of interaction as the limitations of telephones, fax machine systems and emailing systems. In addition, he emphasizes that in distributed collaborations, people prefer to communicate in a small group while many people are involved in the overall design process. Additionally, Chiu [7] states that data preparation and transmission takes a long time to be transmitted and it takes even longer if the CAD drawings are not standardized and need to be converted. Moreover, Li et al. [35] state that though the technology is very useful to construction industries, the misunderstanding among designers is a major barrier in its adaption into the industry.
Lack of convenience in the process of knowledge allocation	Brewer et al. [4] state that while some industries are comfortable using IT/ICT within their organizations, others that are most concentrated in the construction team are far less capable in performing using IT/ICT. Moreover, Sequin and Kalay [53] discuss that interpretation of data produces many semantic ambiguities, which results in miscommunication among design professionals.
Using ICT to improve knowledge allocation	Scardamalia and Bereiter [50] emphasize that computer-supported collaborative environments provide users with tools for posting knowledge production into a shared working space. This results in progressive interaction and participation among members. In addition, Lahti et al. (2004) emphasize the role of collaborative technologies, called FLE-Tool, in supporting design and providing knowledge and collaborative designing in the design process.
Loss of control due to current ICT utilization	Craig and Zimring [10] presented a computer-supported study for unstructured collaboration using a web-based online environment that was used by a graduate-level architectural studio. This system diminished the managements' control over the pace of interaction as the members felt that they were outsiders to the real activity of the studio. Consequently, there was no guarantee of immediate responses over design tasks in the CoOL (Collaborative On-Line) studio.
Quality achievement through higher communication level	To improve the collaboration and enhance the communication among design professionals, Stewart [58] designed a web-based collaboration tool and Christiansson et al. [8] developed collaborative CAD and Computer Supported Collaborative Work (CSCW) tools.

7 Results and Analysis of Substantive Selective Coding

The final outcome of the selective coding analysis phase was the development of an IT-integrated design collaboration engagement model, which we named the IT-integrated design collaboration (IT-DC) Engagement Model. Figure 3 illustrates how each category are linked together to form the IT-DC Engagement Model.

As depicted in the IT-DC Engagement Model in Figure 3, different layers (such as context, casual conditions, phenomena, action strategies and consequences) were defined as a consequence of the GTM explained earlier. Thus, in each layer, the corresponding categories are represented. In addition, different groups of categories supporting different variables are presented with different colors in each layer. Therefore, the categories related to feedback, control and functionality are colored with green, red and blue respectively in the appropriate layers. Moreover, in this study, the categories are linked based on taxonomic analysis [56]. The model presents a flow of categories from general to specific (top to bottom). It starts by describing the context or background problems of IT-integrated design collaboration to the factors that can engage design team members to participate in IT-integrated collaborations.

The IT-DC Engagement Model presents that the manual coordination problem and the factors of human inconveniences from using technology are the two main problematic issues in Malaysian design collaboration process. As depicted in the model, "*Manual coordination problem*" specifies all the challenges and issues which make communication difficult for design team members. Examples include unclear responsibilities, workload, members' multitasking, human attitudes and so on. "*Factors of human inconvenience from using technology*" specifies the factors which make it difficult for design team members to use IT/ICT. The examples are lack of high technology knowledge, ill-prepared for technology acceptance, deficiency in having powerful technological communication, server going down as a reason of communication problems and so on.

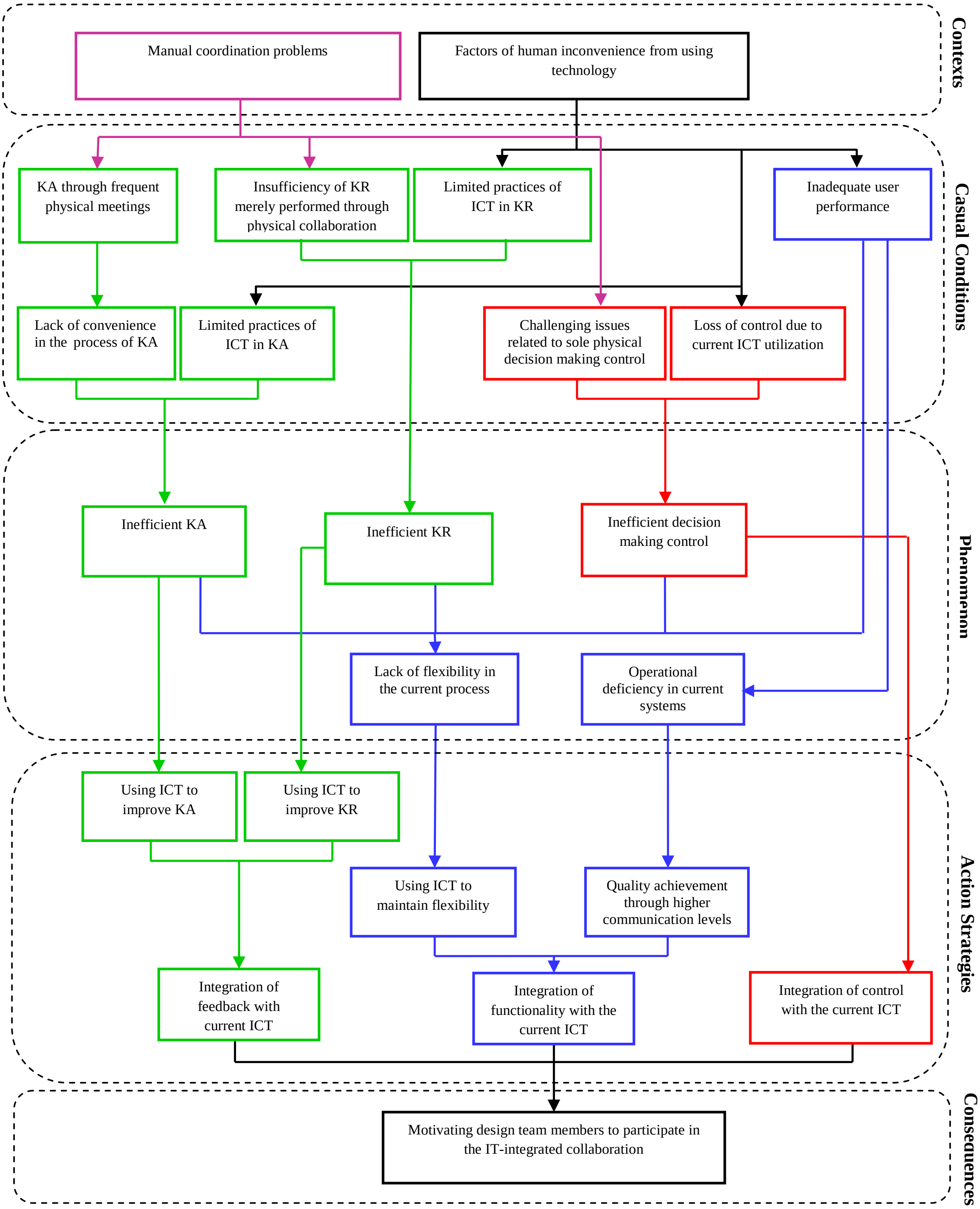
The difference between these two categories is that "*Manual coordination problems*" emphasizes the challenging issues while disregarding IT/ICT integration, while "*Factors of human inconvenience from using technology*" emphasizes the challenging issues with regards to IT/ICT integration into the processes. The manual coordination problems comprises of 1) lack of professional's convenience in the process of knowledge allocation which is resulted from the process of knowledge allocation which is most often performed through frequent physical meetings; 2) insufficiency of knowledge retrieval merely performed through physical collaboration; and 3) challenging issues related to sole physical decision making control caused in non-collocated sites. Similarly, factors of human inconveniences from using technology covers 1) limited practices of ICT in the process of knowledge retrieval, 2) limited practices of ICT in the process of knowledge allocation, 3) inadequate user performance from using IT/ICT, and 4) loss of control due to current ICT utilization.

Moreover, the study found that design collaboration among building professionals is very much influenced by five events: inefficient knowledge allocation, inefficient knowledge retrieval, inefficient decision making control, operational deficiency in the current systems, and lack of enough flexibility in the current processes. These five events are the central phenomenon of Malaysia design collaboration process. Among these events, inefficient knowledge allocation is caused by lack of enough convenience in the process of knowledge allocation which is a result of frequent physical meeting in the process of knowledge allocation operated in non-collocated sites and the limited practices of ICT in current knowledge allocation processes. Similarly, inefficient knowledge retrieval is caused by insufficiency of knowledge retrieval process which are currently performed through physical collaboration and the limited practices of ICT in the process of knowledge retrieval in non-collocated sites. Moreover, inefficient decision making control is caused by challenging issues related to sole physical decision making control (for example, in non-collocated design collaborations, the lack of attending regular meeting by professionals might cause the project manager to feel less in control in decision making and managing) and loss of control due to current ICT utilization. Subsequently, operational deficiencies in the current systems are caused by inadequate user performance from using IT/ICT tools. As a result of inefficient knowledge allocation, knowledge retrieval and decision making control along with the main cause of inadequate user performance result in lack of adequate flexibility in the current design collaboration process.

Moreover, the IT-DC Engagement Model identifies that using ICT among professionals in non-collocated design collaboration process for improving knowledge allocation, knowledge retrieval, maintaining flexibility in the processes and improving the quality of user performance through higher communication level are the effective response to inefficient knowledge allocation, knowledge retrieval, lack of enough flexibility in the current processes and operational deficiency in the current systems respectively.

The IT-DC Engagement Model identified three main strategies to respond to the central phenomenon of Malaysian design collaboration process. They include; integration of feedback, functionality, and control in the current IT-integrated design collaboration process. As explained earlier in Section 3, feedback is defined as the knowledge that is allocated to/retrieved from appropriate design team members for updating purpose. Therefore, the above statement declaring ICT to improve knowledge allocation and knowledge retrieval would result in ICT to improve and deliver more efficient feedback to professionals. Therefore, the study claims to integrate feedback with current ICT. In addition, since user performance and the flexibility of technology are the two variables that lead to functionality, then improving the quality of user performance through higher communication levels and using ICT to maintain flexibility would result in ICT to improve professional functions from using the systems. Therefore, the study claims to integrate functionality with the current ICT. Moreover, the study identifies that integrating control with current ICT is a positive response to the current inefficient decision making control. Finally, the consequences or the outcome of mentioned action strategies in design collaboration process including integration of feedback, control and functionality with the current ICT would potentially motivate and engage professional design team members in IT-integrated design collaboration process.

In summary, the IT-DC Engagement Model proposes that professional design team members are likely to be engaged to the systems by integrating feedback, control, and functionality in the IT/ICT collaborative systems during IT-integrated design collaboration. Thus, it would enable building professionals to mitigate process rigidity caused by inefficient knowledge allocation, knowledge retrieval, and decision-making control; and by inadequate user performance, which resulted in operational deficiency.



Note: KA = Knowledge Allocation, KR = Knowledge Retrieval

Figure 3: IT-Integrated Design Collaboration (IT-DC) Engagement Model

8 Validation and Discussion of the IT-DC Engagement Model

We now validate the IT-DC Engagement Model with extant literature to determine the accuracy of the findings and to reveal how the findings differ from established literature. The process of enfolding literature involves comparing the obtained theory with existing literature and examining the similarities and differences and the reasons for these similarities and differences [59]. Through further study of the literature—a requirement for validating grounded theory results—the researcher analyzed different engagement models which could predict the parameters for engaging users to computing systems [38, 26, 60, 61]. Thus, Table 4 reveals this study's process of supplemental validation that was performed through a comparative analysis of the IT-DC Engagement Model with existing engagement models.

Table 4: Implementation of Supplemental Validation by Enfolding Literature

Engagement Parameters / Engagement Models	IT-DC Engagement Model	Said's Multimedia Engaging Design Model [49]	O'Brien and Toms's Engagement Model [39]	O'Brien and Toms's Enhanced Engagement Model [40]	O'Brien and Toms's Enhanced Engagement Model [41]
Control or simulation interaction	✓	✓	✓	✓	✓
Construct interaction	×	✓	×	×	×
Immediacy	×	✓	×	×	×
Feedback	✓	✓	✓	✓	✓
Achievement of goal	×	✓	×	×	✓
Motivation	×	×	✓	✓	✓
Aesthetic	×	×	✓	✓	✓
Enjoyment	×	×	✓	✓	×
Attention	×	×	✓	✓	✓
Challenge or ease of use	×	×	✓	✓	✓
Novelty	×	×	✓	✓	✓
Interest	×	×	×	✓	✓
Interactivity	×	×	×	×	✓
Awareness	×	×	×	×	✓
Functionality	✓	×	×	×	×

Two stark similarities between the IT-DC Engagement Model and the earlier engagement models are identifying control and feedback. They become the two major parameters of engagement in previous models and also in ours. We had found professional design team members willing to be engaged to a system that allows them to be in control. In this regard, results reveal that professional design team members are more likely to lose control in non-collocated sites, either with current IT/ICT utilization or without IT/ICT in manual collaborations as mentioned by Respondent F "One of my projects is located far in the other site and I don't have time to visit every month. Therefore, sometimes when I read the emails, I get shocked as the changes are done without my opinion." This evidence supports our position that future design collaboration system must allow building professionals to be in control when performing tasks, managing and decision making. From the collected data, we had identified that professional design team members require feedback from the system they are using in order for them to continue utilizing that system, i.e., being engaged to it. In our study, feedback is assumed as the working knowledge that is allocated to or received by appropriate design team members.

In our case, the feedbacks were considered inefficient and inconvenient because in some cases where their drawing files were huge, the design team members were unable to fax or email those documents. Respondents E and H complained that "professionals hardly send design output by fax because they are so big" or "email is not convenient as it is difficult to cloud the design outputs". Thus, those documents did not reach the respective design team members as needed, and especially in the cases of communications between non-collocated offices. In this instant, we argue that design professionals do need responsive IT/ITC to improve knowledge allocation or retrieval between design team members. Therefore, we are proposing the inclusion of a feedback mechanism in the human computer interfaces in future IT/ITC systems for improving the knowledge allocation or knowledge retrieval process among design professionals.

In response to the above proposition, Said's multimedia engaging design model [38] had similarly identified control (referred to as simulation interaction) as a feature that allows the child to take the lead or to role-play [38]. She had observed children were more engaged to a multimedia system which allows them to be in control or in charge of their games. This factor was identified as she found that books were preferred over multimedia applications when children would flip through pages and read at their own pace. Therefore, when a multimedia system is designed, it should also allow some form of manipulation that allows the user to perceive being in control. Hence, Said's multimedia engaging design model identified feedback as a parameter of engaging children to multimedia application [38]. The children in her study preferred to find answers from a multimedia system over finding answers from books because the feedback from the multimedia application was immediate and not too slow.

On contrary, we posit there are further enhancements to the context of feedback in our IT-DC Engagement Model. This study not only emphasizes the immediacy of the feedback that is provided by the computing system, but the efficiency of the allocated and retrieved knowledge too. This difference is due to the fact that the design collaboration process is an activity that requires the continuous participation of professional design team members to accomplish a design task or address an agreed design goal [57]. Thus, other than timing and prompt feedback, the quality and efficiency of feedback is important for professionals to accomplish their design task. Likewise, O'Brien and Toms conceptual engagement models [26, 60, 61] emphasize cognitive, behavioral, affective and emotional needs of humans to engage ordinary users to computer application such as game. Among the cognitive and behavioral factors, O'Brien and Toms's [26, 60, 61] engagement models singled out control and feedback as the factors that engage users to the computing system too.

With reference to Table 4, none of the earlier engagement models—such as Said [38], O'Brien and Toms [26, 60, 61]—could wholly explain the approach to engage in IT-integrated design collaboration. Only two common parameters—feedback and control—are acceptable in engaging users to selective computing applications. The study found another factor of engagement among design professionals, i.e., functionality, thus making prior engagement models inappropriate when dealing with IT/ICT systems for building professionals. The requirements for professional functionalities are critical since each professional member requires different aspect of design need in order to perform their design tasks. This study identifies that while IT/ICT facilitates the design collaboration with functional systems that serve the needs of non-collocated collaborations, professional design team members tend to be engaged with the IT-integrated design collaboration. For example, functionality features may include, teleconferencing facilities to reduce the travelling time where the use of web cameras would enable the design team member to check each other's work virtually. In relation to this, Shumate et al. [62] highlighted different teams consisting of different composition of design team members tend to complete a set of tasks in different phases of a single workflow. The urge for project team members to complete their task in a project is more in lieu of their motivation to rehire for another project with the same organization. Therefore, in integrating IT/ICT in their design collaboration process, these individuals need a system to functions according to their requirements. We found Said's [38] multimedia engaging design model and O'Brien and Toms's models [26, 60, 61] are focused on users whose intention to work with multimedia or computer applications is to have enjoyment. On the other hand, our IT-DC Engagement Model is dedicated to users who are motivated to perform professionally with potential rewards of obtaining more attractive and lucrative projects from the same clients. Hence, we claim to establish functionality as a new key parameter in IT-DC Engagement Model. In summary, the most critical parameters to engage professional design team members to IT-integrated design collaborations are feedback, control and functionality.

We now discuss why the extant models are unable to support the engagement of building professionals to IT-integrated design collaboration. Firstly, we found Said's multimedia engagement model having two other engagement parameters which are "achievement of goal" and "construct interaction". We are arguing that these two parameters are ineffective because design collaboration process is an activity already defined by a goal and agreed tasks [57]. These building professionals have been trained to perform their assigned design tasks and duties therefore; these expectations were already set at the start of a project. In all projects, project's goals and objectives are set by a project manager and directed to each professional individual. Therefore, a design professional expects to perform at the same level regardless whether he or she uses any IT/ICT system to complete his or her allocated tasks. Based on this argument, we claim that integrating "achievement of goal" into IT/ICT is not a critical factor in engaging professionals in the IT-integrated design collaboration process.

Similarly, "construct interaction" is not critical because the design professionals are not learning new knowledge as they had been trained to perform to achieve targeted goals in design practice. In multimedia applications, however, children's key objective of using the system is to learn the concepts of multimedia application. Children interact with a system to gain experience, hence in order for them to improve their learning process, they needed opportunities to create rather than having everything already created for them [38]. This learning process do affects their cognitive and behavioral thinking. As earlier mentioned, design collaboration is an activity that requires the participation of individuals to accomplish an agreed design task or address an agreed design goal. Therefore, design professionals do not need to interact with a system in order to learn about it or gain experience to perform their tasks. In their cases, design team members must also work with a predefined budget and deadline. Thus, we can assume that professionals have already obtained sufficient experience and learnt the system during prior training or experienced sessions before they actually perform their assigned task in a collaborative design work. This observation is supported by Ibrahim and Paulson [63] who found project team members in the early design stage are mostly working in tacit-dominant knowledge areas, i.e., somehow they already know their individual roles and contributions to meet a building project's goals for a particular design stage. Therefore, even though "construct interaction" is an important feature to engage children in multimedia applications, we claim that it is not critical for professional design team members to interact and get engaged with the system as they already have their professional goals in mind.

Nevertheless, the most emphasized parameters of O'Brien and Toms's [26, 60, 61] engagement models are emotional and affective human needs. This element of the model is concerned with interface design and the engaging factors that satisfy users' emotional needs to the system interface. For example, the model identified that during the period of "engagement", the system is supposed to retain users' attention and interest and reduce distraction while they interact with the interface. Likewise, engagement occurs when some information attracts and encourages users according to the users' prior knowledge, intrinsic motivation, as well as when interfaces are visually appealing and well-designed. However, we claim these factors are not dominant in the process of engaging design team members to the IT-integrated design collaboration process, because the knowledge that the professionals retrieve or allocate are those expected and known by each professional members.

The study found similarities and differences are observed among the models proposed by O'Brien and Toms in 2005, 2006 and 2008. Therefore, these models are not suitable for engaging design team members in IT-integrated design collaboration processes as we had argued above. To this end, we had limited this study to identification of factors that would engage professional design team members to IT/ICT collaborative systems. In summary, we posit that IT/ICT systems do not support the professionals functions adequately thus making them less engaged in certain collaborative tasks. Their engagement motivation stems from performing competently as a professional instead of attaining enjoyment during the performance of their tasks.

9 Conclusion

This study has integrated HCI in design collaboration process to recommend designing new engaging interfaces for the systems that are based on human needs rather than organizational need in developing countries. This paper identified the human needs that would engage design team members to the IT-integrated design collaboration process by proposing an IT-DC Engagement Model using GTM. The IT-DC Engagement Model states that by integrating feedback, control and functionality in the IT/ICT systems during IT-integrated design collaboration; it would enable building professionals to mitigate process rigidity caused by inefficient knowledge allocation, knowledge retrieval and decision-making control. It would also support them to mitigate inadequate user performance resulting in operational deficiency. Consequently, this model was validated through a comparison with existing models of engagement. The comparative validation approach affirms two similar engagement parameters –control and feedback– while highlighted a new parameter –functionality—in the IT-integrated design collaboration process. Therefore, we are recommending that when designing the interface for an IT/ICT system for design collaboration, it is critical that the system provides professionals with control and sufficient feedback allowing seamless knowledge allocation or retrieval in addition to allowing the design professionals to function professionally during non-collocated collaboration process. Therefore, we would like to recommend further studies on designing and developing interfaces that integrate the three parameters of engagement for improving IT-integrated design collaboration method for professionals in practice besides improving current professional training curriculum at tertiary level. We believe that with improved training and curriculum development for building professionals in developing nations, we can expect to see the increase of professional collaborations between nations worldwide who have to collaborate on international funded projects.

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