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Integrating Nanotechnology in the Design Process: An Ethnographic Study in Architectural Practice in Egypt

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Abstract: Design and building technology are widely separated in the architectural professional practice, an issue often discernible in developing countries. Architects mostly acknowledge building materials and technology as facilitators for design near final design stages; a process that might dismiss many of the benefits that could have been attained were it engaged early on within a framework of informed appropriation of technology. This paper presents the findings of an ethnographic study that investigates how this gap could be bridged by means of understanding how nanotechnology – both as process and product – affects designer's rationale early on in the design process. The study provides a thick description of the design decision making process of a group of architects working on a residential project in an architectural firm in Egypt, and how it was affected by nanotechnology design knowledge at early design stages.

Keywords: Integrated Design Process; Nano-enhanced applications; Architectural Practice in Egypt; Ethnography

Introduction

Nano-enhanced applications have been affecting the field of building technology for nearly two decades now, and have ever since been responsible for enhancements that overarch several crucial architectural attributes, such as structural engineering (Bartos, et al 2004), aesthetics (Ritter 2006), safety (Leydecker 2008), and environmental performance (Bakir 2013). Such applications were developed based on nanoscience and nanotechnology, and have been used in numerous buildings worldwide, and even in developing countries in Africa

(Bakir 2011). These enhancements were feasible due to the ability to control matter on the molecular scale. This allowed nano-enhanced materials to be tailored from the bottom-up, hence crossing the fundamental limits of the traditional top-down material creation approach (Leydecker 2008), enduing designed artefacts with enhanced performances.

Research in both material science and architecture has widely discussed these direct gains and properties (Zhong 2012). The scope of such research however primarily addresses applications and their use in construction (Bittnar, et al 2009), and/or the benefits gained in performance (Torgal and Jalali 2011). There is little focus on understanding the impact of a more efficient integration of nano-enhanced applications at early design stages.

This paper attempts to provide a thick description of the design decision making process to understand how nanotechnology – both as process and product – affects architects' design decisions, with the ultimate goal of understanding the relationship between technology and design as a whole. We investigate how the injection of nanotechnology design knowledge in early concept design stages affects decision making by conducting an ethnographic study involving members of an architectural firm in Cairo, Egypt.

With limited access to archival data and research pertaining to the current state of architectural practice in Egypt, it was imperative to conduct a qualitative study to establish a clear and grounded understanding of the day-to-day practices in architectural firms and the rationale behind design decision making upon introducing nano-enhanced applications in early design stages.

Case Study and Approach

The case study chosen for this investigation had to fulfill specific criteria to be considered as a representative sample. First the design firm had to have an established process of design, while willing to participate in a study that requires interventions from outside researchers. It was anticipated that these interventions would represent a burden on participants time-wise due to the frequent presentations by the authors, let alone the cultural acceptance of being monitored during day-to-day practice. As for project typology, a large residential project was chosen to represent the substantially larger portion of current construction work in Egypt, which is mostly built by developers.

Accordingly, the selected design firm was a firm that was established in 2008 as part of an international network launched in 1997 in Doha, Qatar. The Cairo office had developed since 2008 into a mid-size multidisciplinary design firm with nearly 30 personnel, providing consultancy services in urban design and landscape, architectural design, and interior design, for different projects in Egypt and the region.

The selected project was a 10-storey residential building with a total area of nearly 31,000m², on a plot of 5,200m². The client was a well-established real-estate developer who contracted the firm to design a project in the Nasr City area in Cairo, Egypt. The client sought a project with a new approach that would allow them to compete in the market for high/middle-income buyers.

The study started with the pre-concept stage after contract preparation, where the client requested two alternatives for plot utilization; one as an integrated residential complex with shared facilities, and the other as segregated stand-alone buildings. Each proposal was assigned to a senior architect, with a special project coordinator assigned to the team to facilitate client interface. The research was initiated upon launching the pre-concept phase of the project, where most of the beneficial impact of nanotechnology was anticipated, due to the flexibility and creativity at this stage.

Data Collection Procedures

This study adopted ethnographic field observation and interviewing as a strategic qualitative methodology (Fischer and Finkelstein 1991) to understand the impact of nanotechnology on the design decisions and rationale of architects, especially in early design stages.

Ethnography was originally used in social sciences, was particularly practiced by cultural anthropologists, and has grown to include other domains in the last five decades (Berg 2001). Due to the lack of information relevant to the current state of architectural practice in Egypt, this study has hence found ethnography an appropriate tool to understand the nuances behind the process of design decision making in the authors' own community.

We also used participant observation (Guest, et al 2013), where one of the authors was actively involved as part of an architectural design team. He was assigned to design tasks, conduct research, and assist with client presentations. This allowed for in-depth and precise observation of the social and technical interactions occurring in the workplace, and for collecting meaningful and instant feedback from participants during their decision making process. We will refer to this author thereon as the participant author.

Participant observation as an ethnographic field method used since the 19th century currently allows ethnographers to critically engage the ethnographic frame with their own participation (Denzin 2005), which would allow this study to carry out the intended injections where needed and monitor reactions.

Conducting this study required nearly daily visits to the design firm. The duration of those visits relied on the progression of the project and the availability of design team members. As part of the design team, the participant author also had access to client meetings, which was beneficial in terms of observing nuances of architect-client interaction. No interviews were made with client representatives, and the client feedback received was conveyed by both the design manager and project coordinator.

The time frame for the study was approximately three months, and was carried out in the period between June and September, 2015, starting from the pre-concept stage towards the delivery of three alternative proposals for the concept of the residential building.

The data collected was in the form of general field note observations, audio and video digital recordings of all interactions made with personnel of the design firm and the client, images of sketches, and copies of digital files used throughout the design activities. A total of 43 interviews and meetings sessions were attended, of which a total of 24 hours were transcribed and analyzed, including 5 hours of meetings within the firm, 15 hours of interviews, and 4 hours of client meetings.

3.1 Field Observation

Upon launching the study, preliminary informal meetings were held with Cairo office partners (P1), (P2) and (P3), and then with all participants to establish rapport, understand backgrounds, brief all about the study and its goals, and to obtain consent. Once the project under study was selected by the Operations Manager (P1), coordination began with Project Coordinator (C1), where a complete brief of the project and client needs was obtained.

The author was then introduced to both senior architects (S1) and (S2), who had nearly 10 years of experience each and were responsible for the two alternatives agreed upon with the client in the kickoff meeting. (S1) was responsible for the integrated residential complex proposal, and (S2) was responsible for the segregated buildings proposal. Images of preliminary sketches, video recordings of both at work, and copies of documents of previous work were collected. The participant author was also granted full access through (C1) to all AutoCAD and REVIT files used for inception and for the communication of ideas and calculations in the project.

The author maintained nearly 3-hour long daily visits to the firm in the first stage of the project, and field notes were constantly taken. These sessions allowed for not only monitoring project progress and decision making, but also for getting a better picture regarding firm dynamics, individual and collective positions and preconceptions, work practices, and social structures. Such observations were crucial to understand the full social context of the study and its influence on design decisions.

An important intervention conducted by the participant author was introducing basic information related to nanotechnology and nano-enhanced applications to participants when needed or requested. This was in the form of presentations injected at different stages of the project. The purpose of these presentations was to demonstrate the basic technical aspects or explanations regarding nano-enhanced applications and their uses. Notes were taken of any comments made by participants during these presentations.

3.2 Interviewing

Interviewing was one of the main tools that allowed participants to express their individual positions and feedback, besides their individual perception regarding information received from the injected presentations. The total number of conducted interviews was 23, where open ended and semi-structured interviews were conducted with (P2), (C1), (S1), and (S2) throughout the design process due to their key roles and significance. Open ended interviewing allowed for non-intrusive and undirected questions, where each interviewee was left to lead the line of thought. This allowed the participant author to better understand the rationale behind the decision making process. Semi-structured interviews were conducted towards the end of each design stage, after presentations, and towards the end of the study, with the purpose of acquiring more feedback regarding specific points of interest that emerged from earlier interviews and field observations.

The 23 interviews totaled about 15 hours, all of which were fully transcribed, coded, and analyzed. Each interview averaged almost 39 minutes. All interviews were audio recorded, and in some cases video recorded if they included sketches or work done in REVIT or AutoCAD. All interviews – except for one interview with (P2) – were conducted within the firm. All the interviews with (S1) and (S2) were conducted at their corresponding workplaces to avoid distractions, to use time efficiently, and to maintain a more comfortable setting for the interviewees. Some interviews were carried out in meeting rooms for privacy purposes, especially if the topic involved other team members, as was often the case with (C1).

3.3 Meeting Sessions

The participant author attended nearly all project meetings, which amounted to 20 meetings, 15 of which were internal meeting sessions. Most of the meetings were one-on-one meetings between (C1), (S1), and (S2) on one end and (P2) on the other as the project manager. Internal meetings totaled nearly 10 hours, 5 of which were fully transcribed and analyzed due to their relevance to the study. The meetings were 40 minutes in length on average. Two other sessions were external meetings with the client and their different departments; technical, development, and sales, where (P2) and (C1) were the design firm representatives, and totaled almost 4 hours, all of which were transcribed. The remaining three meeting sessions were design workshops held by (P2) and attended by 6 junior architects (J1) through (J6), to resolve issues that arose after the first external meeting with the client. Workshops totaled nearly 6 hours, none of which were transcribed.

All the interviews and meeting sessions were transcribed solely by the participant author and were archived in a database for handy retrieval and access, using Microsoft Excel 2007 for quick and easy retrieval, and were visually represented along the duration of the project to facilitate analysis (Figure 1).

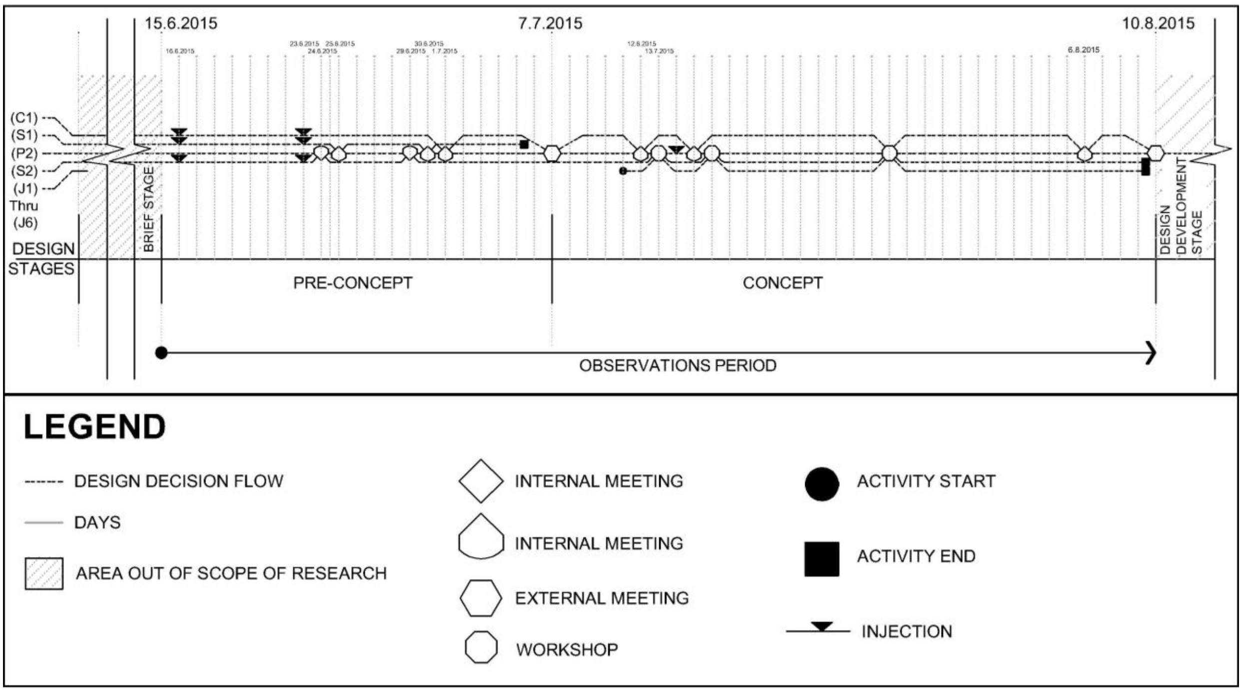

Figure 1 Timeline of the study, showing all meeting sessions among participants in the project

Coding and Analysis

This research adopted grounded theory coding as a basis for analytic induction, where emergent phenomena are identified from the observed data and respondents through a series of steps that would 'guarantee a good theory as the outcome' (Glaser and Strauss 1967; Strauss and Corbin 1998). The basic idea in these steps involves the continuous examination, comparison and reading of multiple sources of data such as field notes, interviews and memos. This process was conducted and maintained in search of emergent patterns.

Those patterns were then translated into sets of concepts that were transformed into codes and then categorized into themes. According to grounded theory coding, the analysis and coding process usually occurs in parallel to data collection. Data examination and coding are done for all notes and transcripts and used for subsequent interviews, with findings that shed light on earlier ones. Two main methods were conducted to arrive at a set of emergent phenomena; open coding and axial coding.

The goal of *open coding* was to identify how architects reacted and interacted differently with nanotechnology design knowledge throughout the process. Transcripts and field notes were continuously analyzed, and conceptual dimensions of these reactions were developed as memos alongside the transcripts. Concepts were established from the memos and were then classified into thematized codes describing how the team perceived and approached nano-enhanced applications. Other codes were developed that address specificities of the type of project, the design process maintained in the firm, and client needs and requirements. None of these were classified with the first set of codes describing reactions to nanotechnology, but were developed later alongside the field study.

Upon recurrence of the same coded themes, and cessation of new significant codes, the stage of *axial coding* was initiated. This involved a refinement of the themes established in the open coding stage and an in-depth study of the connections between them. This allowed for the thematization of a second set of codes that helped describe the impact of nanotechnology on the design process in light of its context.

During several iterations of revision of the transcripts and memos, several codes were developed, revised, added, or eliminated. Higher level patterns of relationships between the different themes allowed for the identification of several phenomena describing the effect of nanotechnology on early design stages, and the role of its specific context in influencing that effect.

Verification

Inter-rater reliability was used to verify the established codes and categories. Typically, inter-rater reliability is a process where concurrence is established among more than one coder in the attempt to find rigor concerning the methods used to code and interpret the results. The goal of this process is to identify the degree of similarity in judgments between independent reviewers with a considerable agreement that indicates high inter-rater reliability (Touliatos and Compton 1988).

The reviewer for our study was a researcher with a master’s degree in the field of health care design and architecture. She was familiar with qualitative analysis, ethnography, and grounded theory coding, and had previously used them in her own research. The reviewer was first introduced to the research problem, and scope and goals of the study. The case study was then explained in full detail while keeping all identities confidential.

In order to provide the reviewer with sufficient insight into the meaning and context of use of the developed codes, a brief guide of all codes was provided containing a short explanation of what each code represented in addition to several examples extracted from multiple transcripts. Three sample transcripts of interviews with three different participants were provided. The reviewer was asked to read the sample transcript carefully, check appropriateness of the provided codes and use any additional codes if needed. A discussion was then initiated to validate the coding scheme according to the interpretation of the reviewer.

For the open coding phase, the discussion involved the different interpretations of the reviewer for the established categories and phenomena. Other rather heated arguments involved alternative understandings of the relationships between the codes and their graphical visualization methods. The codes were then accordingly rearranged, and specific relationships were revisited based on the reviewer feedback.

The final phase of discussion went more in depth through the coding guide line by line and code by code to verify best fit and a revised labeling of the codes and their higher level categories. Once a considerable level of concurrence was achieved concerning the established categories, they were adopted for the rest of the analysis and description.

Thematized Codes and Emergent Phenomena

The identified emergent codes were first seen by the authors to mostly describe the impact of nanotechnology design knowledge on design decisions. Some codes described how participants perceived knowledge, such as *Technical Suitability*. This code described a specific approach by one participant who observed potential uses of specific nano-enhanced applications in the design due to their compatibility with his already established design goals. *Overarchingness* however described how another participant chose to look holistically at the properties made possible by nano-enhanced applications and searched for ways to utilize them. Those two codes were seen as disparate, and accordingly were classified under separate themes.

For instance, the codes *Technical Suitability* and *Hierarchal Perceptions* were classified under the theme *Compatibility* that described how different backgrounds, preconceived ideas and goals drove a participant at a specific point in the design process to simply select a best fit from the available nano-enhanced applications. *Overarchingness*, *Process Vs. Product*, and *Design Tool* were classified however under the theme *Utilization* that described how participants appreciated the abilities made possible, their diversity and scope of potential application, and went further to understand nanotechnology as a process rather than a group of products. Both *Compatibility* and *Utilization,* along with other themes, were seen as facets describing the emergent phenomenon of *Perception of Nanotechnology*, which helped identify the different ways by which participants perceived nanotechnology. Such perceptions were later found to have an important impact on how those participants chose to respond to nanotechnology in subsequent design activities.

The rest of the codes describing the impact of nanotechnology design knowledge on the design decisions were seen to belong to two other emergent phenomena: *Design Affordance of Nanotechnology;* which described how each participant intended to use nano-enhanced applications through their design decisions; and *Resistance to Nanotechnology;* which described the different manifestations of resistance and the reasons that often led to rejecting the consideration of nano-enhanced applications in the design process.

Both of those phenomena, along with *Perception of Nanotechnology*, constituted a set of phenomena describing the impact of knowledge related to nanotechnology on the study. However, we observed other issues – constituting another set of phenomena – that were more related to the project context and were also found to be of impact on design decisions. We identified two phenomena: *Client Accommodation;* which described client satisfaction based on perception of their needs embodied in design decisions, and *Interruption of Information Flow;* which identified specific issues related to information flow within the design team, as well as between the team and client. The five identified emergent phenomena within the two main sets (*Reaction to Injections*, and *Context of Design Decisions*) are illustrated in Table 1, along with the full list of themes and codes:

Table 1 Taxonomy of Emergent Phenomena

Phenomena			Themes	Codes
SET 1:	REACTION TO INJECTIONS	Perception of Nanotechnology	Feasibility	Established; Importance of the Visual.
			Compatibility	Hierarchal Perceptions; Technical Suitability; All roads lead to Rome.
			Borrowing Attributes	Novelty; WOW/Ambiguous; Fashionability.
			Utilization	Process Vs. Product; Overarchingness; Design Tool.
		Design Affordance of Nanotechnology	Adoption	Environmental Solutions; Customizable Tectonics; Spatial Flexibility; Area Efficiency of Artefact; Privacy.
			Adaptation	Freer Design Decisions; Deeper Design; Being Inspired.
			Appropriation	Reciprocal Relation; Tectonic Cohesiveness; Compressibility.
		Resistance to Nanotechnology	Cost Benefit	Affordability; Market Limitation; Logistics.
			Socio-cultural	Not In Egypt
			Fear of the Unknown	Design Gate Keepers; Fear of the unknown.
			Procrastination	Maybe the next stage.
			Incongruence	Project; Typology.
SET 2:	CONTEXT OF DESIGN DECISIONS	Client Accommodation	Owner Complexity	Conflict of Interest; Ambiguity.
			Future Client	It's all about the sell; Seeking the New; The Environmental Benefit.
			Miscommunication	Concealment; Duality.
		Interruption of Information Flow	Client Feedback Leakage	Miscommunication; Managerial blockage; Overloaded experts.
			Operational Segregation	Boxed Process; Team Placement; Logistical Constraints.

The following sections describe in more detail two of the most salient phenomena identified in the study, each belonging to one of the sets mentioned above: *Design affordance of nanotechnology*, and *Interruption of Information Flow*.

6.1 Design Affordance of Nanotechnology

Based on the comparison of data from meetings and interviews, specifically with (S1), (S2) and (P2), the following themes emerged in relation to the reaction of participants to nanotechnology, as illustrated in figure 2:

1) *Adoption*: where participants chose to simply make use of specific nano-enhanced applications to achieve already established goals;
2) *Adaptation*: where specifics in the design approach of participants were modified to accommodate the abilities made possible by nanotechnology;
3) *Appropriation*: where the perception and understanding of participants towards nanotechnology as a process and product allowed them to recognize unachieved abilities and sought their fulfilment.

These themes were evident in the approaches of (S1), (S2) and (P2) following the presentations conducted by the participant author to introduce the research goals and basic capabilities of nano-enhanced applications. (S1) for example expressed a considerable degree of freedom of design, rather than just the direct use of nano-enhanced applications for goal satisfaction. Nano-enhanced electrochromatic glazing solutions allowed for more customizable and flexible levels of privacy for the residential units, which in turn allowed (S1) to "free the architectural line" drawn. While designing the building masses, he was able to focus on the image the client needed and other issues regarding the context, rather than simply being constrained by issues usually faced in previous experiences regarding privacy.

(S2) expressed a need for extra information regarding the environmental details and specifications of nano-enhanced insulation materials such as nanogel and phase change materials. Upon retrieval and presentation of the requested data, (S2) demonstrated forms of *Adoption* by considering the direct use of workable nanogel panels for heat insulation for the walls. After analyzing the specifications however, (S2) moved into another form of *Affordance* where he demonstrated *Adaptation* by conducting a zoomed-in exercise of "deeper Design" to design a door that would allow for ventilation but without acoustic transmission.

(P2) illustrated how nanotechnology allowed him to think as a "sculptor". The ability to design the performance and look of the material from the bottom-up "inspired" him to imagine a more seamless building that depended less on the assembly of different parts, and allowed for a "less pixelated" facade design. (S1), (S2) and (P2) also expressed a need for other possible applications and specific scenarios of performance that were not known to them nor presented by the participant author.

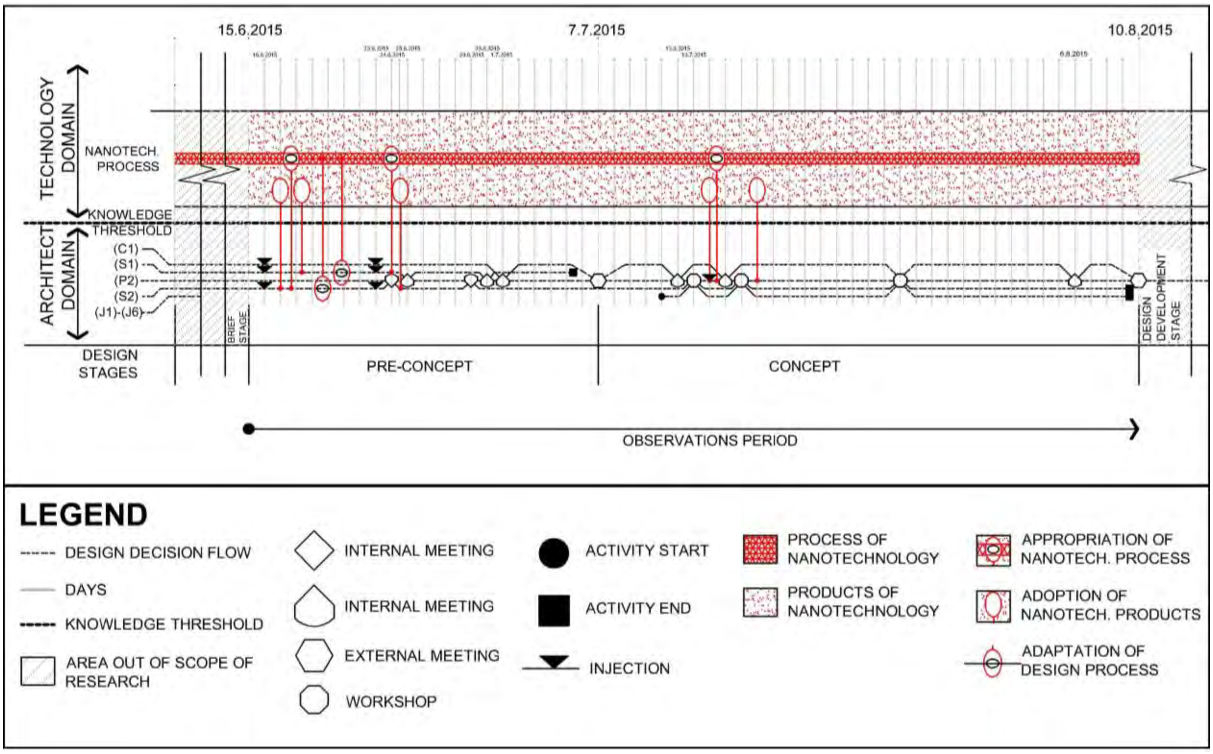

Figure 2 The three themes related to design affordance of nanotechnology throughout the design process: Adoption, Adaptation and Appropriation

6.2 Interruption of Information Flow

Upon analyzing phenomena related to the context of the design process, we observed defects in the information flow between participants and other key players in the project. We put forward two main themes in this regard:

1. *Client Feedback Leakage*, where client feedback loops to managerial and design teams within the design firm failed to resonate with each other throughout the different stages of the design process;
2. *Operational Segregation*, where internal feedback for technical assistance between the design and construction teams and other personnel was rarely established.

We noticed that when specific ideas regarding design proposals were introduced by the design team members to (P2), he would postpone discussing them and rather focus on other aspects of the project, namely its built-up areas and calculations. Other team members thought however that these ideas were relevant to client needs. A contractual clause related to scope of work seemed to always force (P2) to discard some of those ideas. We found later that the specificities of that clause were not clear enough because the client needs were miscommunicated to the managerial team in the briefing stage. This led to several forms of miscommunication between the client and design team. The lack of coordination between (P2) and (P1) thereafter did not allow for project updates and logistical follow ups to be fully addressed. This put the project under further logistical stress, thus hindering chances of complementary developed ideas.

Based on the transcripts, specific loops of information flow were observed to be the locale for this miscommunication. *Client Feedback Leakage* was identified as a significant theme that could be traced to the initiation point of the project; namely the *Contract*. As shown in figure 3, three main entities (client, managerial team, and design team) are engaged in a state of flow of information that leads to the creation of three other sub-entities: the contract, the logistical plan, and the designed artefact. In this process, the *Contract* is drawn by the client and managerial team. Accordingly, the managerial and design teams prepare a *Logistical Plan* allocating time and personnel for the project. Then the *Designed Artefact* is developed between the design team and the client. According to this continuous feedback loop, design decisions are affected if the chain was broken at any point of time.

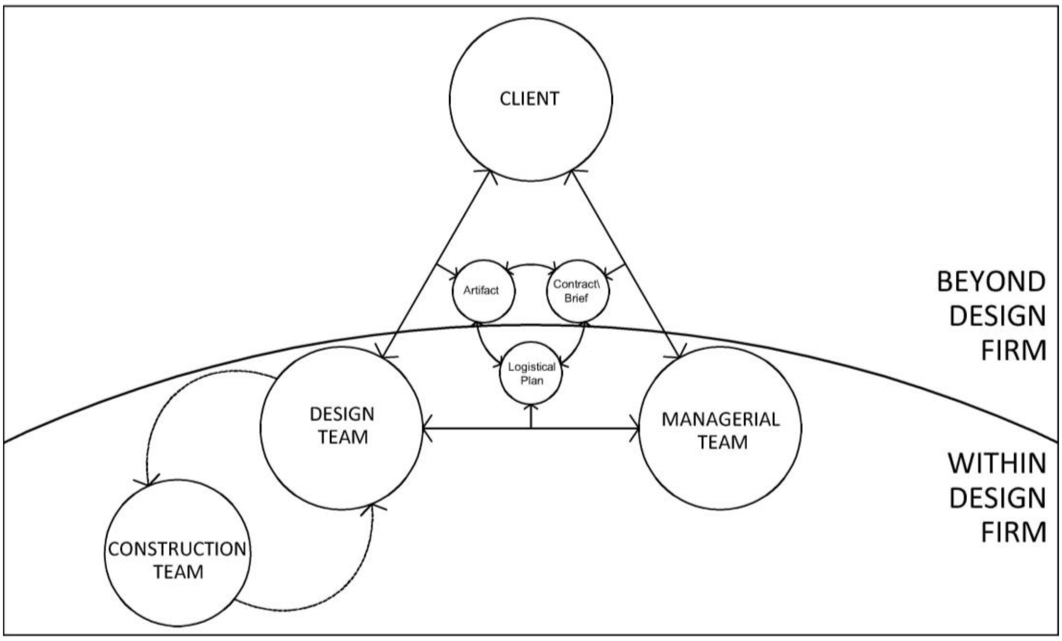

Figure 3 Feedback loop between the three main players in the project: Client, design team and managerial team

We identified other manifestations of interrupted flow of information, where the lack of internal communication for technical assistance between the design team and construction team was evident in earlier design stages. As highlighted by (C1), *Team Placement* was identified as playing a role in such segregation. Issues such as "the design team is in their den upstairs", "...there is a whole department downstairs, why don't they ask?" seemed to shed light on this segregation. *Boxed Processes* was also identified as another form of interrupted flow of information, where design team members would perform tasks as instructed by seniors without "walking the extra mile" and "without trying to think outside the box". *Logistical Constraints* manifested in lack of personnel availability and cash flow also reduced chances of a more integrated design approach, as "departments are barely able to manage the projects coming in".

These themes played a role not only in hindering some of the potential benefits of nanotechnology, but also in hindering other design decisions. These hindrances led to client dissatisfaction and forced the design team to use a more integrated approach in later design phases.

Discussion: The “Design Gates” Narrative

It was anticipated at the onset of this study that it would simply unveil forms by which nanotechnology is received by architects in early design stages, and especially in a developing country like Egypt. The study succeeded in revealing to a great extent how nanotechnology was perceived and potentially used and/or rejected by the participants, while revealing some of the technical reasons behind design decisions. However, due to the richness of the emergent concepts stemming from the dynamics of the observed natural setting – related to both the internal interactions among participants and external interactions with the client – it was apparent that there was an interplay of two sets of phenomena. On the one hand, the direct technical needs of the project and the perception of the potential benefits of nanotechnology were only partially responsible for the architects’ inclination towards affording, resisting, or even degrees in between. On the other hand, the context of the natural setting and the dynamics of the design process played a considerable role in shaping those inclinations.

Upon further correlations between the events related to the aforementioned manifestations, we developed a narrative that attempts to capture how the five emergent phenomena associate with one another, while explaining some of the changes in participants’ positions recorded throughout the duration of the study.

Through several readings into the emergent phenomena and comparisons to events and incidents evident in the transcripts, it appears that socio-cultural dimensions demonstrated different levels of control over design decisions through several points in the project, as described below:

1) Managers/team leaders: The perception of individuals of higher authority in the team would lead to hierarchical retention of valid ideas seen as irrelevant;
2) Teams: With the segregation of teams, certain knowledge thresholds are maintained, keeping them from transfusing knowledge from one team to the other, and thus hindering the development of integrated solutions;
3) Individuals: Educational background, technical experience, talent, position in firm, and social abilities were all individual aspects that allowed for the different perceptions of value within nanotechnology, and accordingly different design decision throughout the design process;
4) Firm processes and logistical plans: Certain design checkpoints were created in the firm that normalized the potential diversity of approaches. This was due to the continuous evolution of the firm, and its effort to maintain its quality and brand while at the same time planning to increase its project capacity;
5) Contract and Brief: The financial capability and socio-cultural background of future users of the building represented an element of control over the process, through the owner

and their complex structure of departments. That control was manifested in the contract/brief document.

We perceive these multi-layered points of control as “Design Gates”, which appear to control and alter design decisions. Although they were informed by specific design knowledge, they create an even more complex context that the design team managers appeared to control, yet are subservient to.

These *gates* have not only affected how the participants perceived nanotechnology and then – regardless of that perception – controlled whether they could use the applications or not, but also have manipulated every other design decision. They played a role in their approval and/or rejection regardless of their appropriateness and validity.

The design decisions hence seem to rather respect a matrix of conceived ideas that fit in the criteria of the “Design Gates” and their location in a power structure. This power structure enforces internal and external constraints, thus creating logical yet managed causalities that facilitate control over design decisions. Figure 4 below demonstrates the scale of the first set of phenomena within the larger and more *controlling* second set of phenomena.

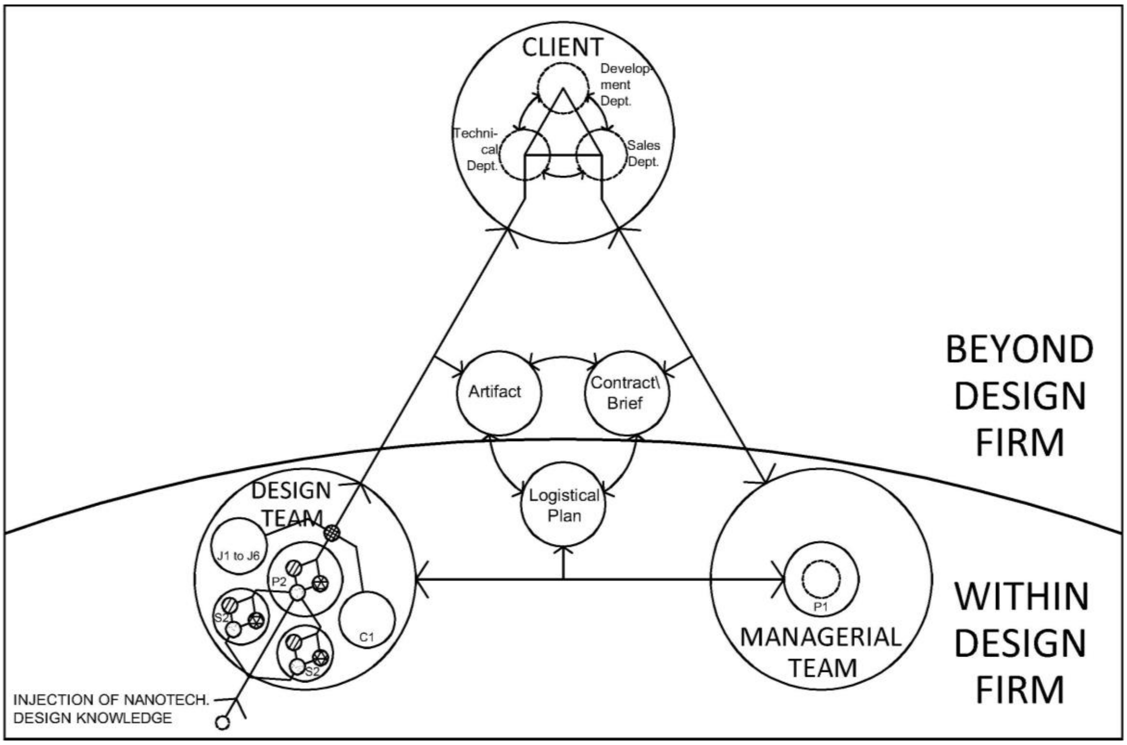

Figure 4 Impact of nanotechnology within the complex context of the project and its “Design Gates”

Further Work

The main argument of this paper is that technology is integral to the creative phase of the design process. The positions discussed above indicate areas of potential theoretical investigation that could help further understand and develop the integration between technology studies and design research in light of social theories, especially in developing countries with their specific social, cultural, and economical specificities that drive many of their design decisions in their own distinctive manner.

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