

SITE PRACTICE: THE ROLE OF DESIGN DRAWINGS WITHIN SOCIAL COMMUNITIES

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The role of drawings within design in the construction projects and production has long been in focus, though only limited studies have been conducted which focused on the role of design drawings in construction phase. The purpose of this study was to elucidate the role of design drawings within different practices in the construction phase. The research is based on an ethnographic study of a case in Denmark. The empirical data were collected through direct observations and semi-structured interviews with site managers, contract managers, foremen and craftsmen. Findings revealed that the construction phase comprises several communities and practices, leading to various uses of the drawings. The results indicated that the craftsmen used drawings to position themselves in the correct location, and that the site managers and contract managers used them as management tools and legal documents. It is concluded that the drawings and the physical building play a vital role in relation to coordination within and across the various communities that are in play within the construction phase.

Keywords: drawings, boundary objects, craftsmen, social communities, site practice

INTRODUCTION

Basically the construction phases can be categorised in (1) the design phase where the drawings are produced and processed and (2) the construction phase where the information in the drawings is interpreted to the physical building. However, it must be emphasised that several social communities, working contexts and practices exist within the construction phase. Thus the drawings have various functions within these practices, and are utilised for various purposes. In this study, the construction phase is unfolded and focus is on the four primary communities (site managers, contract managers, foremen and craftsmen) that are in play on a construction site. The study is based on an ethnographic study of four communities that are related to a construction project in Denmark. The purpose of this study was to elucidate the role of design drawings within the different practices in the construction phase. It is elucidated how the information contained in the drawings are interpreted and translated to the physical building. The study sheds light on how the different contexts affect the individual's perceptions and use of drawings. The study intends to bring about a better understanding of the practices that take place on a construction site and to contribute to knowledge about the various communities that are in play.

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THEORY

Many studies have been conducted which have concerned themselves with how different communities emerge and act within organisations and how knowledge and information sharing takes place within these communities. Lave and Wenger (1991) coined the term Communities of Practice (CoP), which is defined as "Communities of practice are groups of people who share a concern or a passion for something they do and learn how to do it better as they interact regularly" (Wenger 2011, 1). According to Wenger (2011) CoP have existed for many years, and is shaped by the people who engage in collective learning processes. Wenger (2011) defines three characteristics that are essential for establishing a community as CoP, (1) The domain, where members engage and work toward a common goal, (2) The community, where members interact and engage in joint activities, discussions, share information, and build a relationships that enable them to learn from each other, (3) The practice, since members of the community are practitioners who have developed a repertoire of resources; experiences, stories, tools, in other words shared practice (Ibid 2011). Members of the CoP have worked together for several years and have built and maintained a mutual understanding (Ruikar et al., 2008). The different CoP and other communities are separated by professional and social boundaries and peripheries - overlap between two or more boundaries - (Gustavsson and Gohary 2012). Boundary objects enable continuity between these boundaries (Ibid. 2012), and therefore play a vital role.

The notion of boundary object was developed by Star and Griesemer (1989). During the study of Berkeley's Museum of Vertebrate Zoology, 1907-39, Star and Griesemer (1989) used boundary objects to study the interaction between the different knowledge cultures, working toward a common goal, where information is transferred from one practice to the next (Ibid. 1989). They define boundary objects as "Boundary objects are objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use. They may be abstract or concrete" (Ibid. 1989: 393). They emphasise that knowledge is embedded in the practice, i.e. in the tools, procedures, work cultures and technologies that are in play within a certain social world. Thus the boundary objects play a vital role in coordination of information across these practices (Ibid, 1989).

Throughout the last century, many studies were conducted where the functionality and role of design drawings as boundary objects within design and production were examined and elucidated. In general the literature presented here is concerned with three fields. The first part of the literature is represented by Cahill (2000; 2002) and Style (1986). Cahill (2000; 2002) emphasised the role of drawings as primary sources of information, and focused on how this role has changed over the time. Style (1986) underlines three classes of information that are essential for understanding the design intention of the drawings, i.e. (a) what should be performed? (b) Where should it be located? And (c) how should it be placed in relation to other components? Hence design drawings specify spatiality and the information about the components to be installed (Cahill 2002) and (Style 1986).

The second part of the literature focuses on the role and functionality of the drawings in the design phase, as it is emphasised that the drawings as boundary objects are able to transfer information between various practices. Henderson (1991) examined the

role of drawings as visual representations, and whether they act as boundary objects within and across practices in the design phase. She underlined that drawings serve as 'social glue' between various individuals and groups. According to Henderson drawings play a central role in design meetings as "coordination and conflict take place over, on, and through the drawings" (Henderson 1991, 449).

The third part of the literature is concerned with the role of drawings as boundary objects across the design and production communities. Carlile (2002) conducted a study of sales/marketing, design engineering, manufacturing engineering, and production in a product development context. He emphasises that knowledge is embedded in practices and in the technologies, methods and rules of thumb that are in play within different communities, and may therefore be hard to transfer or explicate. Carlile (2002) underlines that models, objects and maps are the most efficient boundary objects and the only categories of boundary objects that support transformation of knowledge.

The majority of the studies focus on the role of drawings in the design phase (in construction projects) and manufacturing/production (outside construction projects). The literature mainly concerns the role of drawings in a production context where the focus has been on product development and other concepts. However this study focuses on shedding light on the role of design drawings within and across CoP and other social communities in a construction context.

METHOD

The present investigation is a part of a PhD study and is based on the initial empirical data collection. The paper is based on an ethnographic study of a case in Denmark, where TN contractor (pseudonym) was design-and-build contractor. The construction firm did not have its own craftsmen; hence it was dependent on various subcontractors, selected by tender and each with a different professional expertise. Thus the temporary organisation is characterised by diversity in professional contexts and practices. Drawings and other project-related documents are exchanged via 'byggeweb', a Danish web-based digital tendering portal.

Methodological approach

I conducted a four week ethnographic study of the construction project, where I spent 6-8 hours a day, 5 days a week on the site. The empirical data were collected mainly through direct observations (Spradley 1980) and ethnographic interviews (Spradley 1979). Reviewing meeting minutes were likewise a part of the empirical data collection. Additionally I tape-recorded the meetings and the workshops. During the first week, the empirical data collection comprised general observations of the ongoing activities on the construction site. The observations gave me insight into the contractor's working practices and working contexts. I noticed that four different communities were at play on the construction site: (1) site managers, (2) contract managers, (3) foremen, and (4) craftsmen.

These communities worked in different contexts and had different roles and responsibilities. In order to gain insight into their work practices and day-to-day work, I chose to observe these communities in their working contexts. I observed the site managers during the construction meetings and during a work day in the site hut and on the construction site. I observed the contract managers during the construction meetings. I observed the foremen and the craftsmen on the construction site, and chose to follow five different subcontractors, a day each, during their working hours

on the site. To observe and follow the subcontractors from early in the morning and to the end of the working day provided me with an insight into their working contexts, the problems they encountered and how they handled these situations. I asked questions during the observations. I interviewed them in the context that they were in. The advantage of conducting interviews with the craftsmen on the site was that they did not have to leave the construction site, so they could still follow the ongoing activities. The disadvantage is that they could easily be distracted by the activities that occurred, and noise that affected the sound quality, which proved to be a challenge during the transcription process. The interview questions were sent to the contract managers via e-mails. Interviews with site managers took place in the site hut, where they spent most of the time.

ANALYSIS

The following sections focus on two types of drawings: floor plans and trade-specific assembly drawings. To understand the role of drawings on this site, I draw on the three concepts (i.e. domain, community and practice), and further unfold the four communities by looking at the factors that are important for understanding the role of drawings. Hence the four communities are analysed on the basis of their (1) contexts, (2) professional backgrounds, (3) responsibilities, (4) technologies and tools, and (5) utilisation of drawings (see Table 1).

Community of practice: Site managers

Site managers are engineers or constructors, and may also have a background as artisans. Four site managers are associated with the project whose overall responsibility on site is the management and coordination of the construction process (control of process, time and budget as well as contractual matters). Concurrently they perform other duties such as procurement, organisation of the construction meetings, safety coordination at the construction site, and contact with consultants, municipality and other authorities. They are provided with technologies such as printer, laptops, iPads and mobile phones. Each manager has floor and layout drawings that are displayed at the office. The physical drawings are organised in binders. They receive and share drawings and other documents through 'byggeweb', a Danish web-based digital tendering portal.

Site managers need to coordinate the process and therefore organise several internal (site managers) and external (the various gangs) meetings during the week. During the internal meetings the discussions take place over the drawings since the drawings are used to coordinate the work. During planning meetings they use both the physical drawings that site managers bring to the meetings, and digital drawings displayed on a projector, and interchange information to update each other. Although formal meetings are organised where discrepancies, conflicts and challenges are discussed, a significant information sharing takes place during the breaks, and other informal conversations.

They organise external meetings with the various trade contractors in order to coordinate and plan future work. Each community has various interests in the meetings: site managers are interested in a continuous process, foremen are interested in obtaining a schedule, while craftsmen's interest lies in having information about where and when to start. During the meetings, the floor and layout drawings are both used to point at and to mark certain locations, and as planning and coordination tools, since new plans are devised on the basis of the drawings. Nonetheless drawings

become legal documents when disagreements and discrepancies occur between site managers and other communities (e.g. consultants). Hence the various versions are filed and used as evidence.

Site managers are members of a CoP on the site as they act within a joint professional domain, where they interact with each other, help and support each other and discuss challenges occurring on the site in order to find solutions.

Social community: Contract managers

Contract managers are engineers or constructors, and may have a practical artisan background. Each trade contract has one contract manager who is responsible for managing the trade contract and the gang on site. He usually runs several concurrent projects. His responsibilities are allocation of resources (e.g. manpower, materials and equipment) to the various projects, providing drawings to the construction sites, obtaining tenders from suppliers, contractual matters and participation in construction meetings. Contract managers primarily use iPads and mobiles on site. In addition, they use physical drawings during construction meetings.

Contract managers' professional background is similar to those of site managers. The factor that distinguishes their roles is their working context, as the contract managers only have the responsibility for their sub-contracts and the gang on site. In case the drawings do not contain required information, it is their responsibility to provide the gang with the information. Given that they are only responsible for their own contract processes, they do not visit the site as frequently; foremen are therefore their pivotal link to the site. In spite of being responsible for the gang on site, they participate as independent entities and communities during site meetings. They are not members of a CoP on the site, but function as members of the CoP acting outside the site, i.e. within their organisations. They share knowledge and information with their colleagues in the organisation, seek experience, and discuss and find solutions together with them.

Drawings are used as management tools and legal documents, e.g. if there are conflicts, discrepancies or disputes between contract managers and site managers or between contract managers and consultants.

Social community: Foremen

Foremen have practical artisan background, supplemented with professional courses that make them thoroughly versed in process management tools. A gang usually has one or two foremen (depending on the size and organisation of the gang) who are primarily responsible for the organisation of construction work on the site. Concurrently they are responsible for piecework, materials procurement, resource allocation (e.g. manpower, materials and equipment) on the construction site and organisation of foremen meetings in order to pass on drawings and other crucial information to the gang. Most of the foremen are provided with iPads and mobiles, which are used to show the drawings. The main tools used in this context are drawings and artisan tools such as ruler, hammer, pencil (e.g. carpenter pencil, concrete pencil), working knife, drills, screws and lifting tools (e.g. crane and lift). They have no access to 'byggeweb', hence the drawings are sent to them by their contract managers via e-mail, or local file sharing systems. They are practitioners and build the physical building; however this role is hampered by administrative tasks (e.g. piecework, wages and materials procurement).

Foremen are the only community on site who inhabit more than one social world. They are primarily craftsmen, but have been recruited to carry out the role of foremen, which implies that they step into a new position, where they serve as a liaison between, on the one hand, gang and site managers (site), and on the other hand, gang and contract manager (firm). They play both roles simultaneously, and must ensure that needs and interests of both communities are met. In spite of their role as craftsmen, they are not members of the same domain in which the craftsmen act, as they still retain their position as foremen among the gang. They can shift from the role of craftsmen to the role of foremen, and vice versa.

One of the objects that allows shifting between the roles is the drawing which in this context is used as management tool and to build the physical building. As a management tool, the information (e.g., quantities, dimensions and locations) is used to devise delivery schedules, and to calculate the time consumption. To build the physical building they need temporal and spatial information in order to position themselves in the building.

Foremen are not members of a CoP, but act as individual social communities. During planning meetings, they contribute with construction knowledge that enables construction managers to devise schedules and coordinate work. They inform and update contract managers in relation to the construction process, as contract managers are not on the site as frequently. Likewise they are a pivotal link between the gang and site managers since the gang contacts foremen if drawings are inadequate, or if there are challenges on the site which requires action from site managers. Thus foremen play a pivotal role in enabling communication across the three communities.

Community of practice: Craftsmen

Craftsmen usually have professional training (e.g., bricklayer, carpenter, plumber, or electrician). They go through an apprenticeship, where they become thoroughly versed in the construction materials and artisan tools. The main tools utilised within this community are drawings, ruler, hammer, pencil (e.g. carpenter pencil, concrete pencil), working knife, drills, screws and lifting tools (e.g. crane and lift).

Craftsmen involved in a gang have fixed roles and perform different tasks at the construction site. For instance, a gang consisting of 10 men will be divided into small groups (usually 2-3 men) who are assigned different tasks. Most of the craftsmen work in permanent teams that are moved from project to another. The craftsmen, who have worked together for many years, know each other's professional and personal boundaries and have built a mutual understanding. The team is therefore a pivotal focal point in relation to information sharing on the site. If they bump into unknown challenges, they will try out a solution by using their tools and draw on their knowledge and experience. They discuss the possibilities and limitations of the physical building and their tools in order to address the situation. The craftsmen use the breaks and informal meetings to coordinate the work and tell stories about challenges that they encountered during the day. The informal conversations therefore play an important role in relation to coordinating and updating the gang.

But in order to start and carry out their work they must place themselves at the correct location in the building. Therefore, they use the information in drawings (e.g. elevations, dimensions and locations), to position themselves in the building and in association with other components. The assembly drawings are used to understand the details about how the components should be assembled, whereas floor plans provide spatial information. When they start on a new location, they place themselves

on the location and hold the drawing in their hands to see whether there are discrepancies between the design drawing and the physical environments. Subsequently, they will put the drawing on a horizontal surface in order to see where to start. In order to remember the dimensions and elevations, they write the numbers up on the walls or other components. Once they have gained insight into how the work is done and where to place themselves in the building, they put the drawing aside (typically in a wheelbarrow, along with other tools). The drawing will not be used again until they start on a new location or encounter a challenge (e.g. collision with other components). In case of collision with other components, each gang will consult their own drawings, as they do not have the professional prerequisites to understand the trade-specific information that the other drawings contain. In this specific situation, the physical building plays a vital role because the building comprises various professional boundaries and therefore enables coordination across these boundaries.

To carry out the work, the craftsmen need information about (a) when work is initiated, (b) where on site it must be performed, and (c) how it should be performed (e.g. in relation to other components). Drawings coordinate their work by providing information about (b) where the work is performed and (c) how it is performed in relation to other components, while schedules - devised from drawings - provide information about (a) when work must be commenced. The role of the physical building as coordinating object is enhanced (e.g. when drawing is inadequate) as it provides information about (c) how the work is performed in relation to other components. For instance, a plumber disregards the drawing if it shows his pipes to be installed in the same elevation as vents. In this case the physical building enables coordination across these two communities that work on a shared location on site.

Table 1: The role of drawings within the four communities and practices.

	Site Managers	Contract Managers	Foremen	Craftsmen
- Context	Site hut	Office/site	Site hut/site	Site
- Professional background	Constructor	Constructor	Artisan training	Artisan training
	Engineer	Engineer	Additional courses	Apprenticeship
- Responsibility on site	Site/process management	Trade contract	Task coordination	Carry out the construction work
	Procurement	Resource allocation	Piecework	
- Tools and technology	iPad	iPad	(iPad)	Construction tools
	Computer	Mobile phone	Tools	Drawing
	Drawing	Drawing	Drawing	
- Utilising design drawings	From drawing to plan	From drawing to plan	From drawing to plan /physical building	From drawing to physical building
	Legal documents/filed	Legal documents/filed	Filed	Put aside/Disregarded

Craftsmen are members of various CoP. They act within joint professional domains and communities, and work toward a common goal. Members of various CoP have the same professional background that distinguishes them from other communities.

DISCUSSIONS

Site managers play an administrative role at the site, and act in a common domain. They organise formal and informal meetings where they update each other, share

information, discuss various options, find solutions and coordinate future work. They constitute a community of practice on the site where they work within their own professional and social boundaries, and work toward a common goal. They use drawings as management tools (e.g. devise schedules) and legal documents.

The various contract managers do not share a domain of interest (Wenger 2011) on the site, but have some common characteristics which enable them to interpret and use drawings in the same way on the site. They act as individuals since they are not part of a domain in which they can exchange information and have a common goal: they constitute an independent social community. However contract managers are members of a community of practice, acting outside physical environment of the site. Within this community the drawings play a role as management tools and legal documents.

Like contract managers, they have some common characteristics that enable them to interpret and use drawings in the same way on the site. Foremen are not members of a CoP on the site, but can bring information across the communities. They play a vital role on the site because they are a link between the three communities, and transfer information across the boundaries. They are a vital link between the gang and site managers and between the gang and contract manager. On the site, they play both the role of craftsmen and foremen: they draw on their artisan practices to carry out the work and put their administrative skills into play in order to solve managerial challenges. They use drawings as both management tools and to build the physical building.

On the contrary, the craftsmen are practitioners and act within a shared domain. They are members of well-established CoP on site, and act within a common professional and social domain, where they have shared practice and work toward a common goal. The small teams interact with each other on a daily basis. During breaks and informal conversations they coordinate work, and tell stories about the challenges that they encountered during the day, and how they were solved. They interpret information in drawings and put their professional knowledge into play to build. Once they have gained insight into what to build, how to build and where to build (Style 1986), they put the drawing aside and commence the work. If the drawing is inadequate they will disregard the drawing and use the physical building in order to coordinate the work with the other gang. They only need the information in drawings in order to build, once they have gained insight, they will disregard the drawings and will not file them as site managers and contract managers do.

The analysis indicates that the four communities act within their professional and social boundaries, which implies the need for objects that can enable coordination across these boundaries. Hence the drawings and the physical building play a vital role as boundary objects since they enable coordination within, and across the boundaries. Drawings enable coordination between site managers and craftsmen, as site managers use drawings to devise schedules that form the basis for the work that the craftsmen must perform. Additionally, drawings are the basis for contract between site managers and the various trade contracts, and can be used as legal documents.

On the contrary, the role of drawings as coordination tool, within and across the various gangs, is weakened, since they also use the physical building to coordinate the work. The physical building forms the common basis for all craftsmen as they will be working on a common location. Although craftsmen are looking at their own drawings, they point at the physical building in order to coordinate the work. In this

case the drawings are disregarded. Likewise the physical building plays a pivotal role as a coordinating object during the meetings. Although the participants are looking at a drawing, they use the building (e.g., a staircase, main entrance, large hall etc.) as a point of departure and navigate through the building from that point, in order to coordinate the work.

During joint meetings the site managers use layout drawings to coordinate work with the various gangs. They come to the drawings, pointing to them and marking certain areas that are to be discussed during the meetings. However the study indicates that some drawings do not enable coordination across the boundaries, but are used solely within the boundaries of various communities. For instance the trade-specific assembly drawings enable coordination within the boundaries of each subcontractor (i.e. across contract managers, foremen and craftsmen, who are connected with the same trade), and across the boundaries of site managers and the specific subcontractor.

Floor and layout drawings involve several professional boundaries, whereas trade-specific assembly drawings are rarely used during joint meetings. Hence some assembly drawings function as silos across the subcontractors because they are highly trade-specific, and do not enable coordination across these boundaries. However some floor drawings contain trade-specific codes and symbols, which can entail that they do not enable coordination across professional boundaries. In this case the physical building plays a crucial role, as a coordination tool, across the boundaries.

CONCLUSIONS

The analysis revealed that the construction site comprises several divergent communities, each with different contexts and practices. Hence the roles of drawings within these communities are varying and ambiguous, since they are utilised for various purposes.

The study indicates that drawings play a pivotal role in enabling coordination, both within but also across various boundaries. Layout drawings serve as boundary objects across the boundaries, whereas trade-specific drawings do not enable coordination across the boundaries. However the physical building plays a crucial role as boundary object, since it can transfer information within and across the social communities and the communities of practice. Furthermore the study shows that drawings play a vital role within the different communities as drawings are used to devise new plans (e.g. schedules), and play roles as management and coordination tools, legal documents, and representation of design information.

Apparently, there are two well-established communities of practice in construction projects; (1) site managers, and (2) craftsmen. Furthermore the study shows that there are two loose social communities; (a) contract managers, who have an administrative role, and (b) foremen who are an important coordinating factor, playing a role as an information carrier across the three communities.

Given that the present study was based on a construction project in Denmark, a design and build contract, the results cannot be generalised. However the study provides insight into site practice and the role of drawings within the various communities in the construction phase.

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