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Epistemic Features of Representational Artifacts in Cross-Disciplinary Design Practices: a Location Planning Workshop for an Outpatient Center

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EPISTEMIC FEATURES OF REPRESENTATIONAL ARTIFACTS IN CROSS-DISCIPLINARY DESIGN PRACTICES: A LOCATION PLANNING WORKSHOP FOR AN OUTPATIENT CENTER

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ABSTRACT

Design processes in collaborative cross-disciplinary arrangements are a subject of growing interest in both research and practice. In such settings the design knowledge is generated through interactions across expert communities of practice. Representational artifacts such as not only drawings and sketches, but also interactive computer models are used to facilitate this interactive process. In spite of a relatively well-established body of research on the role of objects in cross-disciplinary design practices in AEC, not much is known about learning that occurs in the context of these practices as they are mediated by representational artifacts. To this end, this study aims to explore diverse epistemic practices that emerge around a complex representational artifact (RA) in the form of a computer simulation model. To explore these features, the paper presents an exploratory study of a location planning workshop for a new outpatient diagnostic center in the Netherlands in which a RA was introduced to support discussions regarding the form and structure of the outpatient health services being developed. Findings suggest that the RA instigated a collaborative effort at the boundary between disparate domains of knowledge: healthcare service design and the planning of the built infrastructure to support these services. Furthermore, the fluid nature of the RA objectified the unit of analysis in service design and, at the same time, informed the design of the built infrastructure for healthcare provision. The paper calls for further research into the epistemic features of objects in cross-disciplinary design interactions.

KEYWORDS: Collaborative cross-disciplinary design, healthcare services, epistemic objects, exploratory case studies, engineering project organizations.

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1. INTRODUCTION

Although the importance of the project front-end has been emphasized for a long time (Morris and Hough 1987), it is a relatively recent development that substantial research is being undertaken on planning and design in the domain of architecture, engineering, and construction (AEC). The relatively small amount of inquiry into design issues in AEC is arguably due to the fact that costs incurred through design are generally minuscule when compared to construction and operation of projects. However, as projects in the built environment increasingly require substantial collaborative efforts across multiple organizations and professional disciplines, research on design in AEC is developing rapidly.

While the early studies in this domain shared a relatively prescriptive stance on design issues, this research trajectory has more recently taken the direction of descriptive research informed by a pluralistic array of methods and theoretical perspectives. The reason for the prescriptive position of the earlier design studies might be attributed to the fact that they substantiate theoretical concepts originally developed in the context of industrial design, where, in contrast to AEC, the new product development process is relatively well-structured. These studies on design provide a number of valuable findings on, for instance, identifying the optimal sequence of tasks on the basis of their information dependency (Austin et al. 2000) and strategies for overlapping dependent design activities (Bogus et al. 2006). Findings from the prescriptive stream of design research have found relatively limited application in managerial decision-making due to the inherent difficulty in practically assessing information interdependencies between tasks. A number of more recent studies, by contrast, focus on the micro-level of design processes and emphasize the important role of design artifacts in in the design process from the knowledge exchange and knowledge development perspective (Ewenstein and Whyte 2009; Luck 2010; Di Marco et al. 2012; Iorio and Taylor 2014).

Although above studies dedicate a significant amount of scholarly attention to the role of artifacts embedded in design practices, no studies in the AEC domain have thus far specifically focused on learning processes that occur when an ambiguous representational artifact is introduced into cross-disciplinary knowledge practices of design. In an effort to bring this subject of interest as a field of inquiry into the realm of engineering project organizations, we draw from organizational research that, although conducted outside the AEC context, is of great relevance for analyzing the processes of organizational change and cross-disciplinary collaboration through artifact mediation of human activity (e.g.,Miettinen and Virkkunen 2005; Nicolini et al. 2012). To inform the inquiry on the epistemic features of representational artifacts at the boundary between disparate communities of knowledge and practice, we conducted a case study in which the development of a new healthcare service was made into an object of inquiry by means of its epistemic features.

The research is positioned in the context of a healthcare outpatient facility project, as an epitome of cross-disciplinary design that requires frequent exchanges of knowledge between disparate disciplinary domains as they manifest in their respective communities of practice. The rapidly changing concepts under which healthcare services are nowadays provided make healthcare facility design an intensive learning environment.

Having positioned the study in the cross-disciplinary design issues debate in AEC and having introduced the research setting and approach, we next summarize the structure of the paper. We begin with a review of selected design studies in architecture, engineering and construction projects. We then introduce the research setting and findings of the exploratory case study that was used to inform the inquiry presented in this paper. After presenting and discussing the findings, we mention some of the implications of this area of research and conclude with potential areas for future study in this domain.

2. BOUNDARIES AND EPISTEMIC WORK IN DESIGN

The bulk of more recent research in the domain of AEC design has taken a relatively descriptive analytical stance in an effort to address the pluralistic nature of design organizations in that do not lend themselves to deterministic explanations easily. The dominant theoretical discourse of the recent design research seems to have relied on interpretive case studies (e.g., Boudeau 2013) and social network analyses of interactions between decision-making agents in project networks (e.g.,Chinowsky and Taylor 2012). Prominent examples of descriptive design research in AEC are the recent studies that explicate the role of objects in team interactions (e.g., Harty and Whyte 2009; Luck 2010) as well as studies of collaboration in global engineering networks (Di Marco et al. 2012; Iorio et al. 2012).

Studies that focus on the role of objects in design address the patterns of practices (Harty and Whyte 2009) that emerge when design experts use objects to coordinate their activities (Luck 2010). Findings of this research stream stress the role of shared models used to bridge different domains of knowledge and practice. These studies also report that the observed interaction supports not only the exchange of explicit knowledge, but also informal and tacit knowledge that should be shared in design activity (Dossick and Neff 2011). Similar issues have been found in the context of global engineering teams. In this setting, engineering work is undertaken in project networks, where members from diverse organizations in different countries collaborate and share resources in an effort to produce a common outcome. Studies of collaboration in global engineering networks stress the importance and role of boundaries that separate disciplinary members within teams as well as different teams from each other. These studies, more specifically, found that facilitators improve the performance of diverse teams in a virtual and distributed setting in that they gather and distribute knowledge across different domains, thereby acting as boundary spanners and information brokers (Iorio et al. 2012) between communities of different cultures and expertise domains in project networks. Similarly, one of the outcomes of this stream of studies is the notion that boundary objects can be used as instruments to mediate conflict across disparate knowledge domains in virtual engineering teams (Iorio and Taylor 2014). Given the obvious importance of boundary-crossing activity in interdisciplinary work, the boundary object research is relatively well-established within the AEC body of scholarly literature. However, the epistemic features (i.e., learning with things) of artifacts used in cross-disciplinary design practices are still largely overlooked and, as a result, relatively unexplored. As a result, the motivation behind the present study is to explore how learning occurs in the context of cross-disciplinary work mediated by representational artifacts.

Few studies within the AEC domain explored this subject. Ewenstein and Whyte (2009), for example, discuss the *technical*, *boundary and epistemic* roles that objects have in the production of design in teams. Whereas technical objects are considered to convey fixed information about the artifact, in their boundary role they enable interactions across disciplinary boundaries through their interpretive flexibility. The epistemic role of design objects, finally, is attributed to the features that enable the unfolding of design learning through incompleteness and ambiguity of these artifacts. Luck (2010), moreover, contributed to the understanding of interactional phenomena through which design unfolds as an interactive process mediated by artifacts.

Even though the above studies approach the epistemic role of objects in design practices, they do so in on an aggregate level, by considering, among other things, how visual representations and diverse physical objects trigger learning in the design processes. In this study, by contrast, we aim to begin an in-depth exploration of diverse epistemic practices that emerge around a complex representational artifact (RA) in the form of a computer simulation model. We were specifically interested in the epistemic features at the boundary of different communities of practice.

Particularly relevant for the focus of this study is recent work by Nicolini et al. (2012) who study the role of objects in cross-disciplinary collaboration from a pluralist perspective. This research emphasizes the different types of active work that objects perform in motivating collaboration and allowing participants to work across different types of boundaries. The second study we will refer to is research by Miettinen and Virkkunen (2005) who study how organizational practices and routines are changed through representational artifacts such as models and concepts, which are then turned into objects of inquiry to generate alternative organizational practices. In line with recommendations from above studies, we continue with introducing the research setting and method that was implemented to study the epistemic role of representational artifacts in the context of service-infrastructure boundary for healthcare planning and design.

3. EXPLORATORY CASE STUDY OF LOCATION PLANNING FOR AN OUTPATIENT DIAGNOSTIC CENTER

In present-day conditions, healthcare is often designed as a set complex services delivered to the demand-driven market of patients (McKee and Healy 2002; Saltman et al. 2006; Gibin et al. 2009; Meijer et al. 2010). The design of such processes requires the involvement of a variety of medical disciplines and areas of expertise. The built infrastructure that supports health-care processes, on the other hand, is equally sophisticated and it is very often planned and designed in isolation from the health-care process design (Farrington-Douglas and Brooks 2007; Codinhoto et al. 2009; Kagioglou and Tzortzopoulos 2010).

As a result, there is substantial risk that soon after hospitals and ambulatory care units are delivered to the health organizations and patients, they become obsolete and unfit for purpose. To overcome this risk, methods for planning and design should be sensitive to the dynamics of the medical processes and provide solutions that follow these changes. Moreover, coordinating the individual knowledge contributions into a coherent whole requires a thorough understanding of the interactions between different parties in the design effort. The aim of this study is to provide a novel perspective for the issues at the boundary of service provision and the built infrastructure that supports them.

More specifically, rather than focusing on buildings and their systems as the main unit of analysis, the overarching perspective becomes *service design* (Weerawardena and McColl-Kennedy 2002; Jaw et al. 2010; Edvardsson et al. 2012). In line with the service design perspective, design and construction process of buildings in healthcare can be analyzed as "hard infrastructure" whose purpose is to seamlessly support the activities of the medical process in the long run. Since the built environment professionals and the healthcare practitioners are distinct communities of practice, learning needs to occur on both sides in order for collaboration to take place. Using this notion as a cue, this exploratory study sets out to investigate how learning occurs at the boundary of healthcare services design and the built infrastructure that supports these services. The context of this learning is the introduction of a complex representational artifact with an element of ambiguity into the cross-disciplinary collaboration.

3.1 Research Setting

The exploratory case study we conducted involves a project in which a major regional hospital was supported in the planning and design efforts for outpatient diagnostic centers. The context of the case study is the Dutch healthcare system that is undergoing a transition towards a demand-driven market of services (Cramer et al. 2014). One of the things that this concept involves is the decentralization of routine healthcare treatments such as general-practitioner (GP) referred diagnostics. To this end, the hospital developed a project of an outpatient center that would move these routine examinations outside the main hospital building. The goal of location planning effort was to find an appropriate location for the provision of health-care given the geographical distribution of demand.

The researchers were involved in the project in the role of the technology support team with the task of improving the business case for the construction project of the outpatient diagnostic center to accommodate the routine diagnostics. This support was thus broadly in line with the action research approach through participant observation (Jorgensen 1989). The researchers liaised with the radiology clinicians team as this organizational unit was driving the outpatient diagnostic center project.

The information for solving the location problem included hospital admission lists with data about the types of treatments and geographic location of the patients. The researchers' involvement in the project coincided with the development of a GIS-based tool for exploring the location of medical diagnostic centers. The representational role of this tool is next described in more details.

3.2 Developing the Representational Artifact

The developed tool included an agent-based simulation environment with a GIS link. The representational features of the tool were designed through a graphical user interface for easier validation between the researchers and healthcare practitioners. The goal of this effort was to explore the catchment areas translated into market shares for different geographical arrangements of the diagnostics service. In such a way, the GIS-based tool was in the role of a representational artifact (RA) (Miettinen and Virkkunen 2005) to support the planning and design efforts for the outpatient diagnostic center that complies with the production requirements from the business plan.

The main components of the tool included the geographic landscape model to represent the specific study area of the region. Additionally, the components included two different types of agents to represent a specific area within the landscape and a specific outpatient center in the area respectively. These components were then linked by a time step based simulation algorithm that models the economic dynamics about geographic patient admissions in the analyzed area.

Figure 1 - Example of a landscape generated within the GIS-based model. The polygons delineate postal code areas. Houses represent centers. Different shades denote the market shares of various centers

In the first step of the algorithm, the different input data is provided and the model landscape is set up as described in Figure 1 above. After the set-up of the model landscape, users can initialize a number of existing centers within the region under consideration. Based on this model landscape the simulation algorithm then calculated the preferred center for each of the patches based on a specific utility function that calculates a numerical indicator for the preference of patients to choose a specific center. As a result, the patients was represented as independent agents decide about the location of their examinations based on a simple preference function that takes into account the distance between the location of their residence and the location of the diagnostic center. A host of other factors, of course, have an impact on the location decision, but at that point were not taken into account in the RA. This, as will further be argued, consisted one of the key features of ambiguity in the RA. During the above described simulation process, users had the possibility to dynamically influence the running simulation in a number of ways. First, additional centers could have been added by clicking on a specific patch. Second, users could change the parameters of service quality and accessibility of the existing outpatient centers. Finally, users could adjust the weight of the preference function.

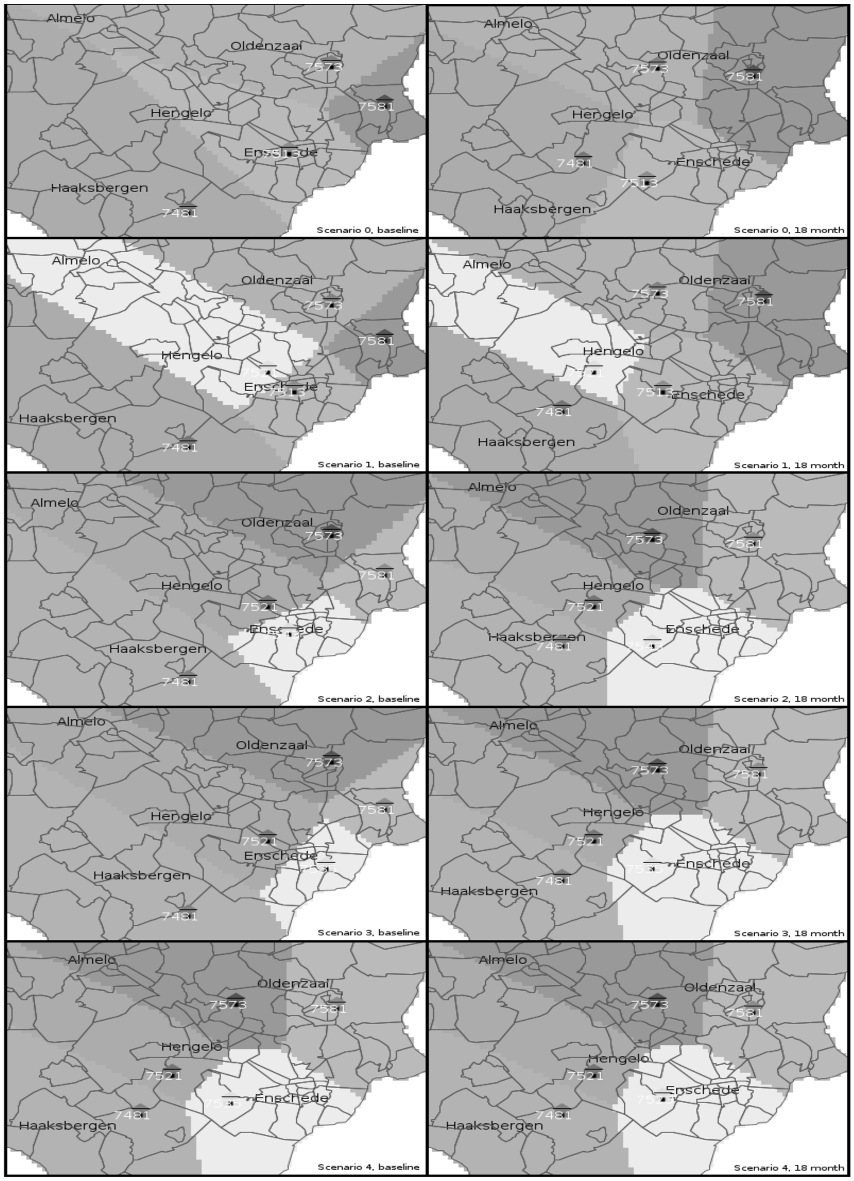

Figure 2 –Outcomes of the GIS-based simulation model for different input scenarios.

The outcomes of the model are shown in the above figure (Figure 2). While the left of the figure shows the initially planned base line position of centers, the right shows the adjusted position of the centers after simulating an 18 months period of the local healthcare market. The above-described GIS-based tool was therefore in the role of a representational artifact (RA) with the aim of generating a visualization of market shares that each of the hospital-managed locations would occupy in different scenarios of the outpatient diagnostic center. Following advice by Joyce (2009), the primary aim of the computational model behind the RA was not to generate accurate predictions of scenarios, but rather to facilitate the decision-making in a diverse group of health-care practitioners in discussions about the locations of diagnostics. Throughout this participatory involvement with the hospital team, the researchers traced how the service design problem was evolving concurrently with ideas about its supporting physical infrastructure of the outpatient diagnostic center. The next section describes a specific workshop in which the researchers met the radiology clinicians to discuss the functionality of the tool that was being developed.

3.3 Cross-disciplinary Interactions in the Location Planning Workshop

The workshop to be discussed took place as one in a series of meetings in this 2-year longitudinal study. The purpose of the workshop was to discuss the possible applications of the RA in the context of location planning. The workshop took place in the midst of organizational changes when the hospital board has put the outpatient diagnostic center project temporarily on hold due to financial and organizational reasons. The context of this workshop can be seen as an effort to re-instigate the planning and design discussions not only about the outpatient diagnostic center project itself, but also about service redesign, as will be seen in the present section. This, at the same time, summarizes the reasoning behind choosing this particular workshop for studying the epistemic role of the RA at the boundary between the built environment and healthcare services communities of knowledge and practice. The following table gives the composition of the participants in this workshop and their roles.

Code	Position
Hospital Radiology Department	
H1	Medical manager
H2	Project associate
H3	Project associate
University Research Group	
R1	Research group leader
R2	Researcher
R3	Researcher (observing)

Table 1 – Coding scheme for the workshop

The form of the workshop was such that the researchers first formally presented the content of the tool being developed alongside some basic findings from the analyses based on preliminary model runs. Subsequent to the presentation of the RA, a long discussion took place to evaluate the potential of the tool in the context of healthcare service redesign. The following is a transcript of a conversation that took place immediately after the researcher R2 presented the tool and findings of the preliminary model runs to the radiology department representatives. We chose to report an extended transcript of the interactions because it gives an overall impression of the context in which the interaction evolves in comparison to short snippets of text taken out of their context. After presenting the transcript, it will be extensively discussed.

1 R2: So if you add the centers around this area [adds several centers by clicking on the GIS map] and runs the model [things start moving around the screen]. Of course, each new center that is added reduces the number of admissions in the others.
2 R1: So let’s say another company comes in and disturbs your market.

3 H1: You are not talking to any other companies, are you?

4 R1: No, not yet.

5 [Everybody laughs for a few seconds]

6 H1: So you can use this model to make assessments whether it is viable to start a new company. Let's say you open a new center somewhere and its market share is very small and there is no reason to open it.

7 R1: Yes, they get pushed out of the market. [Points at the screen with the moving dots and market shares in different colors and continues]. The two blue ones [points at the top of the screen] don't make anything because nobody lives up there so they are pushed off the market.

8 H1: So can you start over? Put one [center] let's say halfway between [city1] and [city2].

9 [R2 makes the requested adjustments]

10 H1: Now put another one, let's say there is another company coming in and they put one somewhere at the border between [city2] and [city3]. This is where the largest volume of patients comes from.

11 [R2 adjusts the model and the discussion goes on about the numbers from the simulation model]

12 R2: Then we can change service quality… So it steals a part of the market from location [city1] and a part from location [city2].

13 [The discussion goes on for several minutes with several location options being discussed]

14 H2: So it takes about 6000 from the main location.

15 H1: What happens if you leave it at the same place but increase the service level? [Can you] make it full service, cheap, and high service and things like that…

16 R1: The service quality is one third of the preference. If a patient would choose something, two thirds would choose to go close, but one third would go according to the service level [part omitted for brevity purposes]. You can now say service quality is more important than travel distance.

17 H2: But that's something we can investigate among patients… [We can] ask the patients what is more important for them.

18 H1: OK, can we try one more? [shows non-verbal signs of interest] Now take the same level of service, but decrease travel distance. Create one with high service in [city1], very close to the hospital.

19 [part omitted for brevity purposes]

20 R2: This is the one close to your main location, service quality 5 [points at the table with admission numbers]

21 H1: 25000, it would make a major impact on our practice [reflective silence]. This hurts already [sounds concerned].

22 [Laughter]

23 H1: Now you can say for example there is a competitor coming in, with the maximum service level, at a convenient location, so what would happen if we adjust our service level, then you would probably see the market share increasing again for us.

24 H3: What do you see in service quality? Because for me, the waiting time is service quality.

25 R1: We just made some up for now. It is a very simple model and we can change it.

26 H1: It is based on assumptions, so if we perform an inquiry with patients, then you can implement it in the model and see what the patients would do [he turns to H2]. We can do this because we are doing the waiting room survey anyway, when we ask patients how do

they feel about the department. The demographic data is known for the entire region and then you can enter the survey results into the model and run it.
27 R2: Sure. The numbers are now of course not accurate, but the relations between values should be kept.
28 H1: This confirms our thoughts about the importance of the first line outpatient diagnostic center. What do you have now? Waiting times, travel distance? [I am asking] [b]ecause these are actually the things that we mention when we are talking about quality and patient comfort [pauses for a second]. We can actually just put these things in a simple list from 1 to 5 and ask the patients what is their grading for it. And if we do that for a 1000 patients and for all the locations, you can populate the model with this data.
29 R2: The model also does not take into account the general practitioners' recommendation. So it assumes that the patients will make their decisions themselves.
30 [H1 nodding his head in acknowledgment].
31 R2: [continues]… I don't know if in practice the decision is made in such a way or…
32 H1: It is a bit more complicated. If the GP is very negative about the hospital, they will say, well: [why don't you] go to [a different location].
33 [Part taken out for confidentiality reasons].
34 R2: But the model does not do that.
35 H1: Well, I think, in a couple of years you will have to take into account the insurance companies… [part taken out for confidentiality reasons].
36 H1: In the end, with all the uncertainties in this model, if we would start an outpatient diagnostic center in the center of [city1], it would not affect any of the other 3 locations, but only [city1]. And if you make it with a high service level, you will probably get the highest referral rate in the region anyway.

It is obvious that even in this short excerpt the conversation between the clinicians and researchers was dynamic and that a number of creative ideas were generated. Arguably, it was the ambiguity and interpretive flexibility of the RA that triggered creative ideas through learning instances on the side of clinical service design. This proposition will be further argued by discussing the epistemic features of the RA at the disciplinary boundary and the cross-disciplinary practices emerging from these features.

Having said that, we also would like to clarify the exploratory nature of this upcoming discussion. In particular, the epistemic features of the RA and emerging cross-disciplinary practices will not be discussed in an effort of establishing logical causality in the positivist discourse of dependent and independent variables. Our intention instead was not to deprive the recorded interactions of their richness and multiplicity and discuss the diverse epistemic aspects as they were observed and interpreted to have unfolded during the workshop discussions.

3.4 Epistemic Features at the Disciplinary Boundary

Introducing the RA into the workshop resulted in several interesting implications. Whereas it can be argued that without it, both groups would have remained more strongly grounded in their disciplinary discourses, now the discussion was on the features of the model, rather than the facility or the medical services, taken separately. The result of this focus was that episodes of learning occurred in both groups which can be observed in the above transcript of workshop interactions. In particular, we propose that it is because the model was presented to the clinicians as incomplete - and relatively ambiguous - (Ewenstein and Whyte 2009) that the actors engaged in a collective interpretation effort in which creative ideas emerged on both sides of the process. This occurred through *ambiguity and interpretive flexibility* through which the RA played the role of engaging individuals in a dialogue and triggering the learning process as opposed to conveying a fixed set of information. In such a way, the cross-disciplinary learning processes were shaped through the object-mediated discussions across the actors.

Ambiguity was clearly one of the prominent characteristics of the representational artifact being discussed. Although the graphical interface facilitated the interpretation of the agent-based simulation it was clear that substantive parts of the interactions were relating to the multiple possible meanings that different features of the RA implied. Similarly, by discussing the possible meanings of the visual representation, the researchers brought the discussion about the facility into the domain of the clinicians' discourse. The clinicians' team took what they deemed relevant from the model to address the organizational design problem they were facing. It is also interesting to note that due to the richness of the model and the brevity of the presentation, the hospital team interpreted the model without being told exactly which aspects of the organizational design problem are addressed by which functionality of the model.

This allowed the RA to be *interpreted flexibly* and differently by the communities of researchers and clinicians, which points towards the role of the RA also as a boundary object. As a result, the interpretive flexibility of the representational artifact can be considered as an antecedent for the creative exploration of ideas about what the model could become as opposed to what it currently is. We continue by introducing some of the cross-disciplinary interactions that emerged as a consequence of the epistemic features of the RA.

3.5 Emergent Cross-disciplinary Issues

As a result of the epistemic properties of the RA as argued above, the interactions at the workshop were exploring different scenarios of locations for the planned facility. One of the most interesting features of these interactions was the emergence of a number of issues outside the location-planning problem for a single facility, the original purpose of the RA and the accompanying model. These emergent issues came about from the side of both service design and well as business development.

In relation to the emergent issues, the most prominent was the notion of *market competition* where the group discussed the consequences of a competitor taking a part of the existing volume of operations. The RA proved to be instrumental in instigating the discussion on market shares and catchment area geographic coverage. More specifically, the model parceled out the overall area into smaller pieces depicted in different colors to represent the market shares that different locations would occupy. Through different scenarios, the group explored the consequences of the different location strategies on the admission numbers. Since the hospital group in question already operated their GP-referred diagnostics in four different locations, these scenarios were aimed at exploring the consequences of closing down some of the existing locations and relocating the services to other locations.

Consequently, the trajectory of the discussion further went into the *business domain* as routine diagnostics are in the area operated on a fee-for-service income system. This implies that the numbers calculated in the model on which the RA was based could have been translated into an estimate of revenues generated through operations of the distributed system of GP referred diagnostics. Although the researchers made it clear that the numbers from the model do not represent the market situation accurately, it was still interesting to observe that this insight did not cause a breakdown in the interactions. On the contrary, the hospital team turned their attention to the possibilities of improving the model by discussing the *service design* aspects of the organizational change.

This involved maximizing the service quality of the new facility, which included different possibilities of clustering several diagnostic services in the same facility. This eventually led to the idea of using a patient satisfaction survey to elicit the criteria for service quality. It is interesting to notice that even the patient survey was discussed in the context of the representational artifact, namely populating the agent-based model with the outcomes of such a survey.

Furthermore, as the interactions in the workshop evolved, *critical outlook* was being developed about the RA in its ongoing stages. In this process, the assumptions of the model were laid bare to the hospital team, which contributed to a critical perspective on the model that is often missing when such systems are implemented into organizational practices in a problem-solving effort. Arguably, the critical perspectives on the GIS-based RA from the side of the hospital team were advantageous in interpreting the information generated by the tool. More specifically, an increasing set of variables that influences the referral process was slowly being revealed as the RA was not reflecting these variables in its agent-based preference function. The relevant criteria included, for example, the decision-making role of the GP in the referral as well as considerations about the different specializations in different locations. As a result, the patients were not entirely autonomous agents that decide about the location of their examinations based on a simple preference function that takes into account the distance between the location of their residence and the location of the diagnostic center.

The above discussed cross-disciplinary issues came about as the RA was introduced into the interactions as an epistemic object. The interpretive flexibility and ambiguity of the artifact contributed to opening up a critical debate through which learning occurred resulting in creative ideas that were exposed and discussed subsequently. This finding is, we believe, interesting enough for itself and we further discuss its implications for practice and research.

4. CONCLUSIONS

Research has long emphasized the role of boundary infrastructure that allows knowledge intensive collaborative work and serves as an important generator of creative ideas (e.g., Miettinen and Virkkunen 2005; Nicolini et al. 2012). In the domain of AEC design, extant research focuses on rich socio-technical design practices into which diverse artifacts are embedded (Harty and Whyte 2009; Luck 2010; Whyte 2011) or boundary objects that are studied in relation with project performance (e.g., Dossick and Neff 2011; Iorio and Taylor 2014). Very little is currently known about the diverse learning processes that occur when an ambiguous representational artifact is introduced into cross-disciplinary knowledge practices of design. In line with this stream of thought, we conducted an inquiry into the epistemic role that a GIS-based computational model had in the process of planning and design of an outpatient diagnostic center for a major regional hospital.

The findings from this inquiry suggest that the above-described tool and model was in the role of a representational artifact that instigated a collaborative effort at the boundary between disparate domains of knowledge: healthcare service design and the planning and design of the built infrastructure to support these services. The findings further suggest that representational artifact supported a meaningful discussion regarding the form and structure of the health services being developed. In this context, visualization and simulation models of healthcare facilities can be viewed as a fluid representation that has the potential to objectify the unit of analysis in service design and, at the same time, inform the design of the built infrastructure for healthcare provision (Miettinen and Virkkunen 2005).

The findings contribute to the body of knowledge in engineering project organizations in several ways. First, the findings contribute to the ongoing stream of research debate on the role of objects in design activities of complex engineering project organizations (e.g., Dossick and Neff 2011; Whyte 2011; Iorio and Taylor 2014). More specifically, the study puts forward the notion that a relatively complex and interactive model (in the case of this research, a GIS-based tool with an agent-based simulation engine) can possess substantial epistemic features that facilitate learning and cross-disciplinary collaboration. This learning unfolds on several different levels, as a combination of the ambiguity and interpretive flexibility of the RA on the one hand and emergent cross-disciplinary issues beyond the immediate content of the RA, on the other.

Having said that, it is important to mention the limitations of this research. Firstly, we must emphasize the exploratory and descriptive nature of this research and findings thereof. More specifically, we suggest that the findings of this study should be viewed as a novel perspective to analyze the epistemic role of models in cross-disciplinary design processes of facility and service design.

In particular, the outcomes of the study should be interpreted neither along the lines of traditional empirical falsification - as in natural sciences - (Popper 2014) or foundational assumptions of determinism, reductionism and essences - as in a lot of 20th century social sciences - (Nightingale 2008). The findings, by contrast, should be interpreted along the lines of interpretive and non-representational approaches for describing the world and organizations that exist in it (e.g., Vaara 2002; Lorino et al. 2011) focusing on multiple forms of dynamic agency to understand organizations as opposed to representations of organizations in the form of positivist models.

In other words, the findings of this study are valuable when they are interpreted as an incremental contribution towards the pluralistic phenomena in knowledge intensive organizations, as opposed to achieving a straightforward causal relationship with statistical generalizability features. All this indicates that the main value of the findings is to provoke new hypotheses to be tested by future research and novel ideas to be readily implemented in managerial practices. This position is in line with recent developments in case study research method (Flyvbjerg 2006; Siggelkow 2007).

Because the analysis presented in this paper is reasonably conceptual, the findings call for further follow-up empirical treatment. This could, for example, be achieved through a longitudinal grounded study encompassing several projects that would allow for a greater level of generalization of the findings. Finally, we suggest that pursuing the research agenda on the role of representational artifacts in practices and organizational routines will gradually lead to a profound understanding of cross-disciplinary and collaborative design as a rapidly evolving domain within engineering project organizations.

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