Learning to cross organizational boundaries in design
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Abstract: The design and exploitation of large, complex projects, is often distributed among different organizations, each with own interests. Collaboration cannot be enforced, since there is typically no clear hierarchy among them. Designers and users must cross organizational boundaries to foster collaboration, if that is to happen. Three healthcare construction projects in The Netherlands have been studied for that matter, and the difficulties found in establishing collaboration suggest that boundary crossing is not only an opportunity to learn from significant others, but a learning challenge on its own. The challenges observed in these projects have been modeled as a board game that simulates the design and operation of a hospital under constant expansion. This game has been played by civil engineering bachelor students in a collaborative design course. Further insights about the challenges for learning to cross organizational boundaries in design were given by students.

Introduction
Since work is increasingly being distributed across and among organizations, there is a growing interest in boundaries in organization research. In the case of design work, boundaries are seen as a result of the common strategy to cope with raising complexity: specialization (Rau, Neyer, & Möslein, 2012). Boundaries are not only the result, but also the condition for specialization, since it is precisely where the distributed pieces of work are put together by professionals coming from both sides of the boundary.

When such encounter does not happen spontaneously, a new specialization may emerge just to put the pieces together. Design itself, as a work practice, emerged to bridge the gap between production and consumption of commodities. Despite all the efforts to take consumers and users into account, or even, to include them as participants and co-designers (Bjögvinsson, Ehn, & Hillgren, 2012), the boundary is preserved; the design practice legitimates itself among others by operating this cross.

There is a recent trend in design practice, for instance, to take the design boundary crossing expertise to other practices, as “glue” for multidisciplinary and collaborative work. Design practitioners claim to have a particular way of working — “design thinking” — that enables targeted and creative collaboration (Kelley & Van Patter, 2005) through the design of artifacts that can represent multiple perspectives at the boundary of disciplines (Bjögvinsson et al., 2012; Luck, 2007; Morrison & Dearden, 2013; Whyte, 2011). Practitioners are supposed to learn thinking like a designer by using these artifacts (Luck, 2012), following design methods, and interacting with the design practitioner, who position herself as more or less neutral facilitator among the disciplines (Lee, 2008).

Following this trend, design curriculums have been created or adjusted to develop this boundary crossing expertise. Beyond the professional marketing, however, there is little evidence and generalized instructions on how practitioners from other areas can learn to cross boundaries from design. An initial step in this endeavor could be to clarify how design practitioners learn to cross boundaries, in the first place.

Previous research on boundaries has focused mostly at the level of knowledge disciplines (Carlile, 2002, 2004; Dossick & Neff, 2010, 2011; Forgues, Koskela, & Lejeune, 2009), with not much regard to how these disciplines are mixed, resisted, and even rejected by practice. There is a risk of imposing the boundaries the researchers find in academic work to the analyzed practice (Akkerman, 2011). With the
aim of empirically investigating the issue, the concept of boundary is set at the level of organization, which we believe to provide a more concrete account of boundaries and learning.

The organization level is not the same as the institution level, though; institutions are indeed one of the most stables forms of organizations, but beyond and within them there lie fluid organizations such as teams and knots (Engeström, 2008). The concept of boundaries applied to the organization level allows seeing the horizontal coordination these fluid forms of organization rely upon. Boundary crossing is a mutual action between different kinds of organization trying to learn from each other (Engeström, Engeström, & Kärkkäinen, 1995). Mutual learning can, of course, lead to new forms of organization, but this is by no means guaranteed or implied by boundary crossing. What is often implied by boundary crossing is improvisation to situations for which the practitioner does not have a prepared response, in other words, a learning challenge.

Three healthcare design projects have been studied for that matter: a medical imaging center, a hospital laboratory, and an elderly housing. By following boundary crossing actions in these projects, it was possible to identify the organizations involved in design, their activities, and their spaces. The cases present further evidence that practitioners learn to cross boundaries while crossing them (Engeström et al., 1995; Hasu & Engeström, 2000; Kerosuo & Engeström, 2003).

This characteristic of boundary work presents a major challenge for design education: how to provide learning opportunities for students if the knowledge to be learnt does not yet exist? Based on the characteristics of the studied projects and inspired by the theory of expansive learning (Engeström, 1987), a board game has been designed and play-tested with design students.

The findings strengthen the learning mechanisms at boundaries identified by Akkerman and Bakker (2011), however, our particular application reframe them as a learning challenges. This paper articulates, henceforth, a vision on boundary crossing that is validated both in design practice as well as in design education. The possibilities of bringing the design boundary crossing expertise to other practices are then speculated.

**Boundary crossing and expansive learning**

Boundary crossing is a phenomenon studied by different knowledge disciplines, with approaches that are not necessarily compatible within each other. There is hardly any agreement among them on what constitutes a boundary. Based on a thorough literature review on the topic, Akkerman and Bakker made a generic definition: “A boundary can be seen as a sociocultural difference leading to discontinuity in action or interaction. Boundaries simultaneously suggest a sameness and continuity in the sense that within discontinuity two or more sites are relevant to one another in a particular way” (Akkerman & Bakker, 2011, p. 133).

Whilst this definition explicates the inherent ambiguity of boundaries, it does not provide enough specificity for our empirical work. We shall construct a better definition of boundaries anchored — or perhaps being the anchor — to organizations. To put the definition into context, the current transformations in work that make boundary crossing relevant are considered.

Capitalism is moving from a mass production paradigm to a co-configuration paradigm, when value generation does not happen inside one firm, but across many firms, including even the customer (Harvey, 1989; Prahalad & Ramaswamy, 2004). This movement has profound effects on the way production is organized. The first and most obvious is that the boundaries between production, distribution, and consumption of commodities are becoming fuzzy. The second is that professional knowledge is becoming more and more specialized to cope with the pressing demands of both sides. In
In this context, professional development cannot solely rely on vertical learning, such as formal training or apprenticeship. If professionals must cross boundaries to get work done, the learning that matters most is the horizontal: learning from significant others that do not share the same expertise.

The theory of the expansive learning has been quite successful in demonstrating learning outside of the school context by following these horizontal movements (Engeström & Sannino, 2010; Engeström, 1987, 2001, 2003). Expansive learning happens when the knowledge to be learnt does not exist and must be created while learning. This is usually the case when members from different organizations need to find a way to collaborate despite their differences. The collaborative practice must be created while learning, what also raises conflict and resistance. Boundary crossing is the action that attempts to establish such collaborative practice, but it is not necessarily always successful.

In this theory, every human activity is oriented towards an object, the thing that can potentially fulfill a need. Within an activity there are many actions, but they may not directly address the object. The object is the overarching concept behind those actions, and at the same time, the material that can fulfill the need (Leont’ev, 1978). The object is indeed the stable point for activity, but it can evolve, or expand to fulfill other needs. Expansive learning means that the activity expands its object by discovering and learning about a new object (Engeström, 1987). A collaborative practice is established when two or more activities orient themselves towards the same object, an expanded shared object (Engeström, 2001).

In this perspective, boundary crossing is an action that rises from one activity towards another, simultaneously, with the purpose of expanding their objects towards a shared object (Figure 1). The action can succeed, fail, or be assimilated by one of the activities. It is also possible that a new activity is formed just to take care of the emergent shared object, a boundary crossing activity. The difference between a boundary crossing action and a boundary crossing activity is the orientation: an action is oriented to a short-term goal, such as a transaction, while an activity is oriented to a long-lasting object, such as a complex project.

Since the object is the underpinning of activity, its expansion implies the transformation of practice in both activities. Change is often surprising and worrisome at the same time; subjects who dare to cross boundaries must improvise in situations for which she does not have a prepared response (Engeström et al., 1995). Akkerman and Bakker (2011) identified relevant learning mechanisms activated by boundary crossing; however, we prefer to refer to them as challenges rather than mechanisms, since they may not necessarily result in expansive learning. We provide a summary of the transformation mechanism processes, reframed as learning challenges in Table 1.
Table 1 - Learning challenges faced by practitioners at the boundary when transforming heterogeneous practices. Based on Akkerman and Bakker (2011, p. 151).

<table>
<thead>
<tr>
<th>Learning challenges</th>
<th>Manifestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confrontation</td>
<td>A disruption of work, a lack, or a problem that is not easily overcome forces the activities to seriously reconsider their interrelations.</td>
</tr>
<tr>
<td>Recognizing shared problem space</td>
<td>Activities recognize their interdependence and the possibilities of solving a problem together.</td>
</tr>
<tr>
<td>Hybridization</td>
<td>The interaction at the boundary generates practices that resemble both sides of the boundary at the same time, in combined flavors.</td>
</tr>
<tr>
<td>Crystallization</td>
<td>Elements of new practices are crystalized into instruments, making them ready for implementation and routine use.</td>
</tr>
<tr>
<td>Maintaining uniqueness of intersecting practices</td>
<td>Differences among activities are preserved, despite the efforts to combine and connect them.</td>
</tr>
<tr>
<td>Continuous joint work at the boundary</td>
<td>A productive exchange at the boundary requires constant dialogue, revising perspectives, and negotiating meaning.</td>
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While expansive learning provides an interconnected model to empirically investigate boundary crossing, the notion of boundaries is still quite vague. Boundaries are seen as discontinuity between activities, but how does discontinuity develops historically? What is this materiality that causes friction and learning between activities? Why boundary crossing is so important for expansion? If boundaries delimit a space, what is the space of an activity? To answer these questions, we turn to organization theory and the production of space.

**Organization spaces**

We propose here to approach boundaries as a feature of organization spaces. According to the production of space theory, there is a close link between space and organization: “Space commands bodies, prescribing or proscribing gestures, routes and distances to be covered. It is produced with this purpose in mind; this is its raison d'être” (Lefebvre, 1991, p. 143). Organization appears first and foremost in space, and later in activity, as an arrangement of form, function, and structure. The materiality of such arrangement is granted by the long historical process of organizing through space, of giving meaning to spatial arrangements, of producing value from them, and so on (Dale & Burrell, 2008). This process does not occur in isolation; in fact, each space is produced in relation to other spaces, as extensions or alternatives:

> In capitalist society [...] the space of work is thus the result, in the first place, of the (repetitive) gestures and (serial) actions of productive labour, but also — and increasingly — of the (technical and social) division of labour; the result therefore, too, of the operation of markets (local, national and worldwide) and, lastly, of property relationships (the ownership and management of the means of production). Which is to say that the space of work has contours and boundaries only for and through a thought which abstracts; as one network among others, as one space among many interpenetrating spaces, its existence is strictly relative. (Lefebvre, 1991, p. 191)

Boundaries in this perspective can be understood as a feature of multiple intersecting organization spaces, such as teams, offices, firms, government agencies, markets, and nations. The reason why these spaces should be kept separate — the abstracted thought — is materialized in boundaries, not necessarily in a smooth way, since each side might have a different interest and power. Drawing boundaries is a political act that is never completely done: there is always some dispute going on to contract or expand organization boundaries (Dale & Burrell, 2008).
In this perspective, boundary crossing is an action that challenges the current boundaries. If it goes too smoothly, the boundary might look like ignored, threatening its status. Its reoccurrence might provoke the emergence of regulating reactions to negotiate crossing at the boundaries, which establish a space of its own. This is the case when a shared object stabilizes amidst organizations. From this reference point, some actions or entire activities might move from one organization to another, or merge.

To summarize the argument articulated here: an organization is the collective production of a shared space between two or more activities. This space is limited by boundaries that are not necessarily physical, but that restrict action in some way. Boundary crossing is an action that spread from one organization to another and involves learning something outside of one’s subject-matter expertise. If such an action is repeated, it might arouse an object and space of its own and become a new activity: a boundary crossing activity (Figure 2). The permanence of this activity might lead to a merge between organizations or a split to an entirely new organization.

This work of “tying, untying, and retrying together seemingly separate threads of activity” at the boundaries is also called knotworking (Engeström, 2008, p. 194). A network model would not be suitable to capture this provisional change, since knots are not logical connections. The model in Figure 2 tries to capture knotworking and boundary crossing with the fluid shape of an amoeba-like organization space. Fluid organization has already been described as amoeba-like in expansive learning (Engeström, 2006, 2008, 2009), but not yet visualized as such. We believe the notion of organization space as socially produced and the derived boundary crossing model can provide more solid grounds for empirical work regarding boundary crossing.

**Research method**

The empirical work is based on a combination of multiple case-study analysis and an experimental setting based on the case findings. The goal is to deepen the understanding of learning to cross boundaries in design.

The cases are healthcare design projects developed in the Twente region, The Netherlands. In the first case, the authors had the possibility of taking an active role in the design process by developing simulations and helping organizing workshops for boundary crossing. The other two cases were ahead of design, so an active engagement was not possible then. In all the cases, the main data source is constituted of partially transcribed semi-structured or open interviews conducted with practitioners involved in the design process during the timeframe of investigation (2-3 months for each case). The interviews topics were drawn from the activity system model used in expansive learning (as seen in Figure 1): subjects, community, instruments, rules, and division of labor associated to the object of design. The model was applied to interviewees’ narrative account of specific actions. Particular attention has been drawn to actions that crossed the boundaries of an organization. By following these actions, it
was possible to identify the multiple activities connected to that design object and to map the organization space they produce.

For each case, a map of organizations spaces, activities, and actions was constructed based on the boundary crossing model (Figure 2). The maps are valid for the timespan of the study, and might not even be very accurate, since the boundaries were already changing from the beginning to the end of the study. The purpose of these maps is not draw a precise picture of the situation, but to give an impression of the learning challenges in crossing organization boundaries.

The focus of this paper is indeed the learning challenges; therefore, we use the processes identified by Akkerman and Bakker (2011) to underscore our cross-case analysis. Narratives excerpts were organized around the challenges to check for commons patterns among the different projects studied. A hypothesis is raised: can design students learn boundary crossing by being purposefully stimulated by these learning challenges? A quasi-experimental setting is proposed: a board game session.

A custom-tailored board game was designed based on the descriptions found in the cases and the challenges found in literature. This game was played by civil engineering bachelor students, in a facility design course. The students were assembled into groups of six, with no control for their personal traits, previous knowledge, or any other variable that could influence their performance. This setting follows the emerging practice of using playful games to test and refine complex constructs that cannot be broke down into isolated variables (Bogers & Sproedt, 2012; Habraken & Gross, 1988; Shapiro, 2013). The comparison is based on the analysis of written learning reports in light of the learning challenges identified by literature. We were interested to check if the game could provide a situation with similar learning challenges faced by practitioners and, at the same time, to track how students reacted upon them. Based on the analysis, a map of organization boundaries for each group of players is provided, and their characteristics are loosely compared to the maps composed out of the case studies. Figure 3 outlines the research method.

The game was designed to assist teaching boundary crossing, since the topic does not favor instruction-based teaching; students have to experience boundary crossing to learn how to do it. The game provides an alternative to the self-organized team assignment, which is the traditional way students learn to collaborate and to cross boundaries in design courses. The game puts a lot more structure to team work; however, it does not instruct what students need to learn. A secondary goal of the game is to
communicate research in a more accessible language than academic papers. Students were in fact required to do both: to read an academic paper and to play the game. After that, they needed to write a group report reflecting on the experience, which is used here as the main data source. A third goal, but not the least important, is to validate the learning challenges identified in literature and generate further insights about them.

**Case 1: boundary-crossing in a medical imaging center project**

The first case is a medical imaging center with state-of-the-art diagnosing techniques such as Magnetic Resonance Imaging (MRI), Positron Emission Tomography (PET-MRI), Computed Tomography (CT), and Electroencephalography (EEG). The project is unique in The Netherlands for its attempt to combine research, technology development, education, and care in the same center.

The boundary crossing action observed relates to the number, size, and shape of dressing rooms in the center. The action started in a participatory design workshop, when a preliminary version of the floor plan was introduced with five dressing rooms for MRI and CT scans. These dressing rooms would be shared among the care providers (Northwestern Hospital and Southeast Hospital). The healthcare operation researchers (University) questioned if this number was enough followed by practitioners from the hospitals. The doubt propelled the design researchers (the authors, same University) to create simulations to predict dressing room's capacity and to visualize the workflow running through space. In the meantime, the project managers of the medical imaging research activity (temporarily located at the University) visited the hospitals and checked how many dressing rooms they currently had and the rules of their use. The issue led to a collaborative redesign of the dressing rooms involving the aforementioned organizations, plus the architecture studio and the imaging technology manufacturer (Figure 4).

![Figure 4](image_url)

**Figure 4** – The issue of dressing rooms triggered an action that involved researchers, practitioners, and architects in the design of the medical imaging center.

Among other actions that crossed boundaries in the project, the problematization of the dressing room was crucial to arouse a shared object between activities, amidst the organizations. They realized together that the object of the center — medical imaging knowledge — was going to be produced by the physical encounter of future activities and for that to happen, shared spaces are essential. Then, the design rationale of enclosed spaces changed to shared, interconnected, flexible spaces. This boundary crossing action is one of the many that are contributing to establish a boundary crossing activity, the
medical imaging center itself, which aims to bridge the gap between technology development and clinical application.

**Case 2: Boundary crossing in a hospital lab project**

The second case is a microbiology and pathology laboratory that decided to move from Southeast Hospital to Northwestern Hospital, who offered space in a new building together with its own dialysis center. The hospital wanted to experiment a new design technology — Building Information Modeling (BIM), that is sought to increase communication efficiency among construction partners. The companies accepted the challenge of using this technology for the first time, which implied moving from a collaborative practice based on 2D printed drawings to a practice based on 3D computer models. The hospital hired an extra consultant for advisory about BIM technology.

The architect was quite concerned of losing his position as the master builder who oversees the design integration to a computer software, while the engineering companies did not know how to start. The contractor took the lead of organizing a boundary crossing activity: a regular concurrent engineering session, when the construction partners would share their drawings, models, and concerns in a collaborative fashion. The new technology was crucial in these sessions because it allowed consolidating the models that each organization was working on: the building shape of the architect, the load-bearing walls of the structural engineer, the pipes of the hydraulic engineer, and the cables of the electric engineer. They could see if there were clashes due to the division of labor, such as a pipe running into a door, and immediately discuss a solution for them.

The process went smoothly until the laboratory bought a new diagnosing machine that required more electrical charge than what was provided. This late requirement was handled by many partners, since it spread changes in the whole design (Figure 5). The hospital represented the laboratory in the concurrent engineering sessions and only later communicated the changes. The laboratory could not understand how and why those changes were made, so they thought it would not matter making a new change from their part.

![Figure 5 - Subjects from the microbiological analysis activity purchased a machine that exceeded the requirements previously agreed upon, what required a lot of rework from construction partners.](image-url)
Case 3: boundary crossing in an elderly housing project
The third case is an elderly housing unit located in a small city, with living apartments and a palliative care center. The unit is being developed by a private company, which acted as client. The client also heard about BIM and required the construction partners to design with that technology, also for their first time. The expectation was that BIM would make design process more creative by bringing all the parties together, especially the client himself. In fact, what happened was far from that.

The architecture studio was quite knowledgeable with the technology and pushed other partners to comply with the new information standard. A file sharing system with version control and comments was setup to host the interlinked models, divided by disciplines. Very often designers would make change to these models without communicating to others. Since the meetings were not as regular and effective as in the previous case, there were a lot of problems due to the lack of communication. The contractor, the engineering companies, and even the client think that is a consequence of the traditional contract adopted. The architectural studio, despite having a structural engineering counselor to minimize constructability issues, over-specified the model before the contractor entered the game.

![Diagram of the construction process](image)

Figure 6 – The facility manager asked the construction partners to provide as-built model for the new elderly housing unit. The partners decided to hire a specialized company to assemble the model.

Late in the process, the client realized that the BIM technology could provide an accurate as-built model of the new unit, from which a maintenance plan could be derived. The partners did not know how to provide it, since each was working in a different model. Actually, none of them wanted to take responsibility for it. Then, the client hired a specialized company to assemble everything together. The model manager had the challenge of interpreting information coming from different sources and make judgments about consolidation on his own (Figure 6).

Despite such boundary crossing action, no traces of a boundary crossing activity or a shared object have been observed in this case. In fact, each partner was more concerned with delivering a finished outcome to the next activity, without worrying too much about what was going to be done with it. This behavior has been attributed not only to the contract, but also to the undergoing financial crisis of the construction sector in The Netherlands.
Learning challenges observed in the cases

We have collected evidence that when practitioners face hard organizational boundaries while trying to come up with an integrated design (including ourselves as participant researchers) they like to introduce new instruments to push the boundaries, what is sometimes called a boundary object (Björgvinsson et al., 2012; Luck, 2007; Morrison & Dearden, 2013; Whyte, 2011). This corresponds to the simulations in the first case and BIM technology in the last two cases.

As useful as they could be for representation and coordination, boundary objects do not dissolve organization boundaries; by making them visible, they can even strengthen those boundaries. Boundary objects are sometimes introduced with the assumption that boundary crossing do not occur by the absence of an explicit bridge. As reasonable as it seems, this assumption neglects the fact that even physical bridges are constructed as part of long process of alignment between organizations (Suchman, 2000). The perceived failure of these objects (Dossick & Neff, 2010; Gottlieb & Haugbølle, 2013; Hannele et al., 2012) suggests that there is more than a technical challenge to boundary crossing. Here, we consider the learning challenges mentioned before in relation to the case evidence (Table 2).

Table 2 - Learning challenges reported by practitioners in the studied cases (interview excerpts)

<table>
<thead>
<tr>
<th>Learning challenges (Akkerman &amp; Bakker, 2011)</th>
<th>Medical imaging project</th>
<th>Hospital lab project</th>
<th>Elderly housing project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confrontation</td>
<td>“Well, the result was good but the process itself... people were just waiting before we could start. That was also new to me. Because what I know is that when I talk to contractor it is easier for me, I can order them, or find these people and make a [fist on the table].” (Facility manager)</td>
<td>“We froze the design and decided to build it. However, during the delivery process, it had to be changed since the end user had bought something else [a machine] for the lowest price. The circuit was overloaded.” (Electrical engineer)</td>
<td>“[...] working in a traditional way and BIM is difficult, in our view. Actually, it is better to form a construction team and then discuss in advance what needs to be done, by whom and how much it will cost.” (Water engineer)</td>
</tr>
<tr>
<td>Recognizing shared problem space</td>
<td>“I don’t know who my users are in fact. It is a problem because making this building [university unit] was a lot easier, much easier. I knew my users. [...] I could speak to them; make a program.” (Facility manager)</td>
<td>“At the moment you begin with the design you never know which technologies are going to be used [...] Now there are extra costs, but still within the project. We knew in advance that changes would come, and we accepted them too.” (End-user)</td>
<td>“We began too late in the process with determining the direction and vision for the construction project and the role of BIM.” (Model manager)</td>
</tr>
<tr>
<td>Hybridization</td>
<td>“Discussing with the architect, if they actually listen, that is definitely a requirement, and we ourselves have to be willing to change our ideas. Because our ideas are fixed as well. Just as fixed as the architect.” (Southwestern Hospital radiologist)</td>
<td>“BIM can’t happen without collaboration, and collaboration can’t happen without BIM. [...] BIM is then something... some people see it as a 3D model, what makes it possible to combine information and make the same information available to everyone.” (Contractor)</td>
<td>“We want the final model with all the adjustments as built to derive a maintenance plan from it. It would be even nicer if we could make such plan during the design phase.” (Client)</td>
</tr>
<tr>
<td>Crystallization</td>
<td>“It is crucial that you have to embed that process [dealing with patients] very well in the layout of the building and then you have to take care of the matters of infrastructure related.” (Northeastern Hospital information analyst)</td>
<td>“The supplied requirements model was under-specified. That model was 60% ready for installations and after three months we have just left it aside. This model was delivered by a third party, since we could not implement in the original.” (Water engineer)</td>
<td>“The three interlinked models did not match very well, so there were problems.” (Contractor)</td>
</tr>
</tbody>
</table>
Maintaining uniqueness of intersecting practices

“We have to be careful always who we involve in the discussion, because the architect is already in some processes and doesn’t want to be taken out, I think. [...] So, we ask a different designer. It is not an architect; it is somebody who is just practical with drawing things in a building.” (Project manager)

“We have seen and asked for changes many times, but you see nowhere a check if these changes are reflected in the drawings. You see never a definitive drawing. If changes are made to the model, the executive responsible, but who controls these changes?” (End-user)

“We have seen and asked for changes many times, but you see nowhere a check if these changes are reflected in the drawings. You see never a definitive drawing. If changes are made to the model, the executive responsible, but who controls these changes? ” (End-user)

Continuous joint work at the boundary

“It is more important that you get people involved in the process than the result. I learned that in other projects. Find them, join them, put them together, and let them speak. Because, in the end... perhaps you could see it differently...” (Facility manager)

“Another great advantage of using BIM and collaborative sessions is that you directly understand certain choices from the partners. In the traditional way, this understanding is difficult to build up, since everyone is busy with his own things. [...] You do not have these interactions by calling or emailing every partner.” (Contractor)

“In this way, the alignment with the different parties happened using a big screen so that problems could be solved in realtime. Alignment must happen in the shop floor, not by management.” (Architect)

From the expansive learning perspective, boundary objects can be better understood as instruments to transform objects that are tangential to organization boundaries, the so-called shared objects (Engeström, 2001). *Boundary instruments*, now renamed, emerge as a consequence of shared objects, not as a pre-condition for them, and they might not even be able to grasp them. Practitioners still have the learning challenge of being confronted to each other and recognizing a shared problem space before they can crystalize hybrid practices into a boundary instrument (Akkerman & Bakker, 2011). After that, chances are that the constant work at the boundary will make these instruments quickly unfit for maintaining the uniqueness of intersecting practices, due to its tendency to contract into the infrastructure of standardized procedures (Star, 2010). Then, a new boundary instrument may be created to support a new cycle of expansion.

This cross-case analysis suggests that expansion in learning also implies expansion in space, the space of organization boundaries. Since expansion can take many years and can result in losses (Spinuzzi, 2011), there is a risk of becoming “expensive learning”. Working under tight schedules and limited resources, design education and professional development might not be able to afford such risk. We think that there should be faster and safer ways of learning to cross boundaries in design.

**The Expansive Hospital: a board game about boundary-crossing**

The cases present further evidence that practitioners learn to cross boundaries while crossing them (Engeström et al., 1995; Hasu & Engeström, 2000; Kerosuo & Engeström, 2003). This characteristic of boundary crossing presents a big challenge for design education: how to provide learning opportunities for students if the knowledge to be learnt does not exist yet?

Design students typically learn to collaborate through group assignments and design studios (Kuhn, 2001; Ward, 1990). When they are following the same course, chances are that they have similar backgrounds and interests. It is difficult to promote confrontation, especially when they can team up to divide the assignment into separate tasks and get a reasonable group grade out of it. Business simulations and games have been tried in design education to provoke such confrontation (Bogers & Sproedt, 2012; Habraken & Gross, 1988; Shapiro, 2013); however, they are typically based on abstract combinatory systems, with finite sets, what does not stimulate the creation of knowledge beyond the possible combinations, in other words, expansion (Hatchuel, 2001).
Inspired by the theory of expansive learning and informed by case data, we created a board game (Figure 7) that let design students learn boundary crossing by trying it, even if they do not succeed. The game plot is a hospital undergoing constant expansion, so all the profits are reinvested in real states development. Each game session simulates a process that takes between 5 and 25 years of a hospital history, with many successive construction and operation rounds. The goal of the game is to increase hospital credibility rating from 10 to 20. This is done by successfully treating patients. If patients are not admitted or lose their satisfaction while being treated, credibility runs down. A hospital with no points of credibility is closed and the game is over. Another possibility is the hospital going bankrupt, with no money left in its own account to pay the maintenance costs.

This is in a nutshell what the players play collaboratively. Conversely, there is another side of the game to play competitive. Each player has her own account, with the sum earned from the hospital account for her duties. What complicates the game is that players have a different earning schema, depending on the role played. There are six roles in the game, with mutually exclusive powers: the architect can define the building shape, the engineer can design the service infrastructure, the builder can implement the design, the hospital director can decide where to invest, the facility manager can maintain the facilities, and the nurse can admit and guide patients across the building. Players negotiate how to use their powers, charging more for their duties, or harming others, for instance. If they play too competitive, the hospital might go bankrupt. The director is the one who can moderate players by choosing different construction contracts — traditional, fast-track, and integrated; however, she is also biased by her own earning schema: she can take a fixed percentage of the hospital account every turn, but if she avoids investing, she is under pressure from all the players. The contradiction between the individual and the collective manifests itself differently for every role in the game, pushing players to do more than just following the rules.

The rules are such that information will likely be lost. The hospital is built with building blocks, each representing one facility type, with a service layer underneath. If players do not know what is already implemented, they cannot decide how to operate or what to build next. There is also a risk of clashing a gas pipe with an existing water pipe when adding extensions, what allows the builder to charge an extra amount. Players receive database sheets to keep information as they like, but that is not mandatory for playing.
The game is a simplified and caricaturized version of what happens in construction projects. The elements, rules, and flow draw from commercial board games such as Cleopatra and the Society of Architects (2006), The Pillars of the Earth (2006), 1830: Railways & Robber Barons (1986), Ugg-Tect (2009), Master Builder (2008) and Knot Competitive (Patrick Crowe). Table 3 highlights how these elements, rules, and flow have been tailored to the learning challenges of boundary crossing.

Table 3 – Learning challenges at the boundary and derived game elements, rules, and flow.

<table>
<thead>
<tr>
<th>Learning challenges (Akkerman &amp; Bakker, 2011)</th>
<th>Game elements</th>
<th>Game rules</th>
<th>Game flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confrontation</td>
<td>Each player holds a role card, with a different power, which is moderated by another role.</td>
<td>Players depend on each other to get the task done and cannot make decisions for others.</td>
<td>Players must negotiate every move. If a player does not want to negotiate, the game is stuck.</td>
</tr>
<tr>
<td>Recognizing shared problem space</td>
<td>All players earn money from the same source, the hospital account, which is limited by the care performance.</td>
<td>If the hospital does not earn money from successfully treated patients, it goes bankrupt and the game is over.</td>
<td>The impact of player’s action on care performance is not clear from the beginning. Only after playing some rounds, they may notice it.</td>
</tr>
<tr>
<td>Hybridization</td>
<td>The design of the hospital is a balance between the different aspects each role contends: cost, usability, sustainability, etc.</td>
<td>The contracts (traditional, fast-track, and integrated) specify who should talk to whom to make the decisions.</td>
<td>Once players understand what they cannot do, they try to influence each other’s decision. Decision becomes deliberation.</td>
</tr>
<tr>
<td>Crystallization</td>
<td>The cables and pipes are occluded once the blocks are built. Players can take notes in a database sheet.</td>
<td>Once the blocks are built, they cannot be touched; otherwise the builder can charge an inspection.</td>
<td>Players who forget to store information rely on others who take the burden. Those become influential in the game.</td>
</tr>
<tr>
<td>Maintaining uniqueness of intersecting practices</td>
<td>Players need to negotiate every move to safeguard their interests and/or the hospital financial health.</td>
<td>There are two winning conditions: the players win as a team at 20 points of hospital credibility and the richest player wins individually.</td>
<td>Players develop identities in the game that may not match the description of the role card or their expected social identities.</td>
</tr>
<tr>
<td>Continuous joint work at the boundary</td>
<td>The continuous hospital expansion requires players to keep the boundary work throughout the whole game.</td>
<td>The game is divided into two alternating rounds: construction and healthcare.</td>
<td>Each round creates a situation that can only be addressed in the next round, an open loop.</td>
</tr>
</tbody>
</table>

**Playing the game with design students**

The Expansive Hospital game was introduced in the course Methods and Strategies for Facility Design in University of Twente’s Civil Engineering bachelors. This is an engineering design introduction based on Pahl & Beitz (1984) textbook. The course alternates between lectures and hands-on sessions for group assignments. One of the lectures introduced the problematic of representing knowledge in design instruments and the importance of keeping a reflective practice for that matter (Schön, 1983). The following hands-on session had the goal of letting them face the issue by playing the board game. Before the game session, students were required to read and write individually a report about a study on how a special contract affected the collaboration among construction partners in a swimming pool project (Cicmil & Marshall, 2005). After the session, they were also required to write a report to be graded with reflections on the gaming experience, this time in a group.

In the actual game session, students organized themselves in groups of six players. The game was introduced without explanations; they had to pick it up from the rulebook and by asking questions to the
authors. It took an average of one hour to understand all the rules and to achieve a smooth game flow. Two hours was the total duration of the session.

After playing, students were also asked — not required — to individually fill out a survey about their experience to contribute to this research. The submissions were almost complete for three groups of players: A, B, and C. The question about the frequency of communication among the roles gave an initial idea on how close or distant was one role from another (Table 4).

**Table 4 - How often each player role communicated with each other (the * sign marks missing data)**

<table>
<thead>
<tr>
<th>Group</th>
<th>Roles</th>
<th>Architect</th>
<th>Engineer</th>
<th>Builder</th>
<th>Nurse</th>
<th>Facility Manager</th>
<th>Director</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Architect</td>
<td>=</td>
<td>Often</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Sometimes</td>
<td>Sometimes</td>
</tr>
<tr>
<td></td>
<td>Engineer</td>
<td>Often</td>
<td>Very often</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Often</td>
</tr>
<tr>
<td></td>
<td>Builder</td>
<td>Often</td>
<td>=</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Often</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nurse</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Rarely</td>
<td>=</td>
<td>Very often</td>
<td>Sometimes</td>
</tr>
<tr>
<td></td>
<td>Facility Manager</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Rarely</td>
<td>=</td>
<td>Very often</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Director</td>
<td>Often</td>
<td>Rarely</td>
<td>Often</td>
<td>Rarely</td>
<td>Rarely</td>
<td>=</td>
</tr>
<tr>
<td>B</td>
<td>Architect</td>
<td>=</td>
<td>Very often</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Rarely</td>
</tr>
<tr>
<td></td>
<td>Engineer</td>
<td>Very often</td>
<td>=</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Sometimes</td>
</tr>
<tr>
<td></td>
<td>Builder</td>
<td>Often</td>
<td>=</td>
<td>Rarely</td>
<td>=</td>
<td>Very often</td>
<td>Very often</td>
</tr>
<tr>
<td></td>
<td>Nurse</td>
<td>Rarely</td>
<td>*</td>
<td>Rarely</td>
<td>=</td>
<td>Very often</td>
<td>Very often</td>
</tr>
<tr>
<td></td>
<td>Facility Manager</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Rarely</td>
<td>=</td>
<td>Very often</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Director</td>
<td>Sometimes</td>
<td>Rarely</td>
<td>Very often</td>
<td>Very often</td>
<td>=</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Architect</td>
<td>=</td>
<td>Often</td>
<td>*</td>
<td></td>
<td>Rarely</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Engineer</td>
<td>Often</td>
<td>=</td>
<td>Sometimes</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Rarely</td>
</tr>
<tr>
<td></td>
<td>Builder</td>
<td>Often</td>
<td>Sometimes</td>
<td>Rarely</td>
<td>=</td>
<td>Rarely</td>
<td>Rarely</td>
</tr>
<tr>
<td></td>
<td>Nurse</td>
<td>Often</td>
<td>Sometimes</td>
<td>Rarely</td>
<td>=</td>
<td>Often</td>
<td>Often</td>
</tr>
<tr>
<td></td>
<td>Facility Manager</td>
<td>*</td>
<td>Sometimes</td>
<td>Rarely</td>
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<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Director</td>
<td>Rarely</td>
<td>Rarely</td>
<td>Sometimes</td>
<td>Rarely</td>
<td>Sometimes</td>
<td></td>
</tr>
</tbody>
</table>

Based on Table 4 data and interpretation of group reports, the organizational boundaries in these three groups were drawn (Figure 8). Since gameplay was not recorded, it is not possible to track specific boundary crossing actions, as done in the case studies. However, the students’ reports mention that there were many attempts to influence another player’s decision, to come along and exchange information, to help with a task outside of own expertise, and to co-create solutions. The reconstructed organizational space reflect the stable result of these actions: group A had a tight-knit construction team, yet a quite fragmented healthcare team; group B had both collaborative teams which did not communicate so much among each other; group C failed to establish teams and made the hospital bankrupt in only three rounds due to the individualistic play style.
Figure 8 – Boundaries within the three groups of players: group A (left); group B (middle), and group C (right).

The varied morphology of organizational spaces in these groups highlights the importance of not taking for granted organizational boundaries, shared objects, boundary crossing and boundary instruments. These are all emergent phenomena that cannot be predicted or determined by material conditions. The game introduced the same conditions for all the groups, but each group created its own boundaries based on the interpretation of the rules, social relationships within the group, personal experiences and other formants. Some groups used the building blocks, some used the information database, and some used concepts such as “the need to collaborate” as instruments to cross the boundaries. Nevertheless, the boundaries prescribed by the game roles, contracts, and economics were not the same as the emergent boundaries because players transformed them while negotiating their positions and moves. We believe this was possible to happen due to the messy, unclear, and expansive character of the gameplay.

The game was designed to provide challenges, not just mechanisms. Play performance is not supposed to increase by mastering the underlying mechanisms, but by actually learning to cross organizational boundaries. The student’s learning reports suggest that while playing the game, they faced the same learning challenges that practitioners face, as designed for (Table 5). Even if they did not succeed in overcoming the challenges, like group C, they still learnt by reflecting on their gameplay.

Table 5 - Learning challenges faced by students (learning report excerpts)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Confrontation</td>
<td>“When some members of the team earn much more money than others, tensions will arise in the team.”</td>
<td>“[…] the Fast-track procedure is a quite fast procedure. There is no discussion at all. […] Therefore the solution will be less optimal. Every actor does the things on his own, without thinking of the consequences for the other involved actors.”</td>
<td>“There was no consultation between the players on the healthcare team which resulted in building unnecessary facilities and going over budget.”</td>
</tr>
<tr>
<td>Recognizing shared problem space</td>
<td>“In our game two of the three team members got less money than the third member. So the next round they divided the money with each other and the third member got nothing. In such case the total profit will likely be lower than if the whole team worked together.”</td>
<td>“[…] building modeling on itself is no solution. If information is available, but people do not want to use the information, (in this instance because it poses advantages for the project as a whole, but would only cost additional time for the architect), BIM is useless.”</td>
<td>“[…] the visualization of the hospital was very helpful. […] While the health care team or the construction team was arguing, the visualization was helpful in order to choose which decisions would be right to make.”</td>
</tr>
</tbody>
</table>
Hybridization | “If the game was clearer at the beginning, the teams could make a strategy to win the game with their team. So they grant each other some money, so that the profit with the team should be higher, than if they don’t grant money to the other team members.” | “All information was stored in a ‘data-base’ to keep track of all the activity. This database contained information of different disciplines and could been seen as a primitive BIM model.” | “The problem for the interdisciplinary design [...] was the interest of the different actors. The facility manager had to build the most expensive blocks to optimize his profit, while the nurse wanted the blocks [...] to retain the most satisfactory for the patient’s treatment.”

Crystallization | “One of the things we did learn during the process of the game was how the different contract forms unfold in real life. It was very interesting to see how these different forms gave very different outcomes to the price of the project.” | “[...] what we learned as a group is that communication is essential to get a sufficient result. [...] Another point we noticed: it is important to document all relevant building information, such as water lines, electricity lines etc.” | “These contracts have (dis)advantages for actors and the different contracts result in different attitudes of the actors and it helps to generate other kinds of ideas.”

Maintaining uniqueness of intersecting practices | “[...] this game showed that nobody cares about anything but his own goal [...] This might sound a little sinister, because in theory it sounds like everybody will work together smoothly, but when the stakes get higher people tend to get meaner.” | “In this procedure [integrated contract] there is a lot of interaction between the different disciplines. They have to discuss about a solution which is in the budget. The budget is for the whole design team. So a lot of coordination is necessary to make a proper design.” | “When every person keeps the different goals of the different person in mind they can take this into account when taking their own decisions and everyone can work together on solutions which bring good long term advantages.”

Continuous joint work at the boundary | “In BIM the different participants share much information about building the object. [...] this sharing of information did not always work well. [...] So there needed to be more interaction between the different participants in the game to make BIM work better.” | “[...] several people had too little information at some point. [...] The most apparent consequence was the need to re-obtain information. This happened multiple times.” | “[...] it was very important that both teams were working together. This means that every person had to keep the general goal in mind. When one person decides to only go for his own goal and personal gain this can quickly affect the entire group.”

**Discussion**

Boundaries have been presented here as the contour of fluid organizations, a marginal effect of the production of shared space among activities. Organizations and their boundaries are historically developed by the contradiction between the needs for local bonds and for global competition in capitalism, reproducing and also resisting global trends such as fragmentation and complexity.

This perspective is relatively new, since most investigation on boundaries often falls to a determinism of knowledge specialization, resulting in compartmentalization or silos in organizations (Carlile, 2004; Dossick & Neff, 2010). They justify the need for instruments (Carlile, 2002; Forgues et al., 2009) or professionals (Brown, 2008; Kelley & Van Patter, 2005) that are capable of reassembling knowledge at the boundary in a neutral or holistic way, ultimately reducing the differences. The political difficulty of keeping boundary work neutral or even the fallacy of such discourse pushes to think beyond knowledge consolidation as a counter-tactic to work fragmentation. While researchers think about reducing differences and reassembling totalities, practitioners are already tying the knots, crossing boundaries on a daily basis to get work done. They do not seek to reassemble knowledge, but to create new knowledge that can fill in the gaps and expand the practice (Engeström et al., 1995). Once in a while, an innovation stems from that.
The relevant challenge for organizations trying to work together may not to be to reduce their differences, but to learn from them. Such learning implies expanding their space towards temporary overlaps, where provisional knots may be tied, where shared objects may emerge, where new activities may be formed, and last but not least, where conflicts must be worked out. Such overlap have been observed in the participatory design workshops of case one and in the concurrent engineering sessions of case two, but there were still many boundary crossing actions that escaped the shared space. Boundary crossing is a workaround for the contradictions of capitalist space, but also a learning challenge for practitioners.

Given this overall picture, a question remains: are there any specific learning challenges for design or any specific responses to those challenges in design? Do design practitioners have a special expertise for boundary crossing? Can such expertise be the “glue” for interdisciplinary work?

Historically, design as a dedicated activity emerged to bridge the gap between production and consumption of commodities, tying one to the other (Dilnot, 1982; Suchman, 1994). Such task requires not only crossing the internal boundaries of production to pitch consumption needs, but also the boundaries that hinder consumption, such as cultural diversity, social heterogeneity, and tradition. Design has drawn attention in society by delivering images — boundary instruments — that tie diverse communities together (Lefebvre, 1991). Indeed, boundary crossing is integral to design. Yet, some design academics claims its own knowledge discipline (Cross, 2001). If disciplinary knowledge is the culprit of work fragmentation, how can another discipline fix fragmentation? The way out of this conundrum is perhaps to move the scope from discipline to organization. Then it is possible to see that design is actually already happening at the boundaries of organizations, not by a single discipline, not by a single activity, but by many co-designers (Loukissas, 2012), with different interests, power, and instruments.

We have observed in the game experiment that even when there is little shared space between production and consumption — in game’s term the construction and the operation round, consumption make its way through design by own effort. Thus, there is also production in consumption, production of use value. The game could have been designed to take only into account the boundaries in production, with greater detail on the division of labor and the design instruments, making a much more realistic image of what BIM technology represents, for instance. However, we preferred to emphasize the interplay between the use value generate at operation rounds and the exchange value generated during construction rounds, which is actually the main source of conflict in the game. Humor is a frequent resource used by players to deal with conflicts and differences, enabling also the emergence of counter-discourses (Gonzatto, Amstel, & Costa, 2010), in this particular case, the criticism about BIM technology.

This research contributes to the expansion of project-based organization research towards social, cultural, and managerial boundaries (Chinowsky, 2011). The derived board game connects project-focused organizations (the construction players) with continuous-process organizations (the hospital players), supporting design students to learn crossing this crucial boundary, not only in space, but also in time. The game helps realizing that all the involved parties must cross boundaries to make design happens, even the so-called end-users. Instead of highlighting the mediation performed by design practitioners at the boundary, this research highlights the mediation performed by any practitioners at the boundary, where inter-organizational design actually happens.

**Conclusion**

Boundary crossing is not a mechanism that can be seemly implemented in a design instrument and mastered by a particular way of “design thinking”, but a social practice that presents learning challenges for all practitioners involved and affected by design. Crossing boundaries requires confrontation,
recognizing a shared problem space, hybridization of practices and the crystallization of such hybrids, while still maintaining the uniqueness of intersecting practices and the continuous joint work at the boundary. These challenges have been observed in three case studies of construction projects and they have underscored the design of a board game. The conclusion of the observation of practice and the experiment of playing such board game is that inter-organizational design happens at the boundaries of organizations, not within the boundary of a single organization.

The vision of organization put forth here is a fluid, in state of change, space that imposes boundaries that are not necessarily physical, but still pretty much material, in a social sense. This materiality is not shaped by knowledge disciplines, but by the contradictions of capitalist space, where the fragmentation of knowledge is just one manifestation (Dale & Burrell, 2008; Lefebvre, 1991).

Boundary crossing have been distinguished at the activity level (object-oriented, long-term) and action level (goal-oriented, short-term), with mobility between the categories: one action can move from one activity to another, even to raise a new object and become a new activity. Instruments can also move from one activity to another, but they do not establish a crossing practice by themselves. For that, a shared object between multiple activities is necessary. The role of space in grounding such object has been highlighted.

The emergence of a shared object and the implied collaborative practice cannot be produced like an instrument, as the outcome of one single (meta)design activity (Fischer, 2010). Collaboration has political, economic, legal, and spatial conditions beyond the technical. Establishing a collaborative practice requires first and foremost that parties have a chance to choose either to collaborate or not. Second, choose how to collaborate. If parties are forced to collaborate for the sake of design, then collaboration may not manifest in practice beyond the discourse that justifies the cooperation with a dominating party.

These were the main findings of playing the Expansive Hospital game under the hypothesis of learning to cross organizational boundaries. We see the game as a practical way to understand and experiment the theoretical construct about organizational spaces presented here. It could perhaps be used to test other hypothesis that would require the same setting. Or it could inspire the design of other games, based on different theoretical constructs. In that sense, games could be considered preliminary experiments that help refining theoretical constructs before actual field studies. They are safer and faster, but no substitute for practice, both for scientific and for learning purposes. The validity of the findings presented here should be corroborated with further inquiry into actual construction projects and related facility operations. Longitudinal studies could track and demonstrate how organizational boundaries develop not only through space, but also through time, revealing the constitution and consequences of the taken-for-granted “increasing complexity” of design organizations.

References


