# Between Theory and Practice: Bridging Concepts in HCI Research

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## ABSTRACT
We present the notion of 'bridging concepts' as a particular form of intermediary knowledge in HCI research, residing between theory and practice. We argue that bridging concepts address the challenge of facilitating exchange between theory and practice in HCI, and we compare it to other intermediary forms of knowledge such as strong concepts and conceptual constructs. We propose that bridging concepts have three defining constituents: a theoretical foundation, a set of design articulations and a range of exemplars that demonstrate the scope and potential of their application. These constituents specify how bridging concepts, as a form of knowledge, are accountable to both theory and practice. We present an analysis of the concept of 'peepholes' as an example of a bridging concept aimed at spurring user curiosity and engagement.

### Author Keywords
Experience-oriented design; Interaction design theory; Engagement; Analytical frameworks.

### ACM Classification Keywords
H.5.2 [Information Interfaces and Presentation]: User Interfaces – Theory and Methods, User-Centered Design.

## INTRODUCTION
The notion of design thinking - i.e. the modes of understanding and acting upon design challenges that characterize designers - has become a topic of much discussion in the CHI community in recent years. While a number of contributions and discussions have developed our understanding of design thinking, there is also a consensus that there is still a need to clarify and articulate (e.g. [28]) what constitutes design thinking, and indeed to discuss how we may arrive at such articulations (e.g. [40]). There are different ways of adding to the discourse of design thinking. Among these, one can draw more or less directly upon existing theoretical positions (e.g. cognitive psychology), 'import', in the terminology of Rogers [39], and develop existing positions and theories within the frame of HCI (e.g. activity theory [22]) or one can develop theoretical constructs from design practice and examples of interactive systems (e.g. design patterns [42]). One of the persistent challenges for interaction design researchers and practitioners is that there often seems to be a gap between theory and the specific design instance; by nature, theories are abstract, since they must account for a variety of instances, and thus they can be difficult to translate and operationalize in relation to the particular design situation. In this article, we are interested in exploring knowledge constructs that exist in the middle ground between theory and practice. Some of the wider known concepts and forms of knowledge in HCI such as patterns and heuristics occupy this space, arguably because they draw upon a wider set of input than the specific design situation, yet are operational and aimed at helping designers address the specific situation.

In this paper, we introduce the notion of 'bridging concepts' as an intermediary form of knowledge residing between abstract theory and design practice and we argue that bridging concepts are distinguished by their ability to facilitate exchange between theory and practice. Articulating knowledge in the form of bridging concepts, prompts us to formulate knowledge in a way that specifies the accountability to both theory and practice. While continuous exchange between theory and practice is important in academia in general, it is arguably even more so for HCI. Within HCI, much theory has been imported from other more established disciplines such as psychology and sociology [39]. For interaction design researchers and practitioners, this prompts constant articulations of how and to what extent newly imported theories are useful. To complicate matters, the subject matter of research in HCI – ever-evolving interactive interfaces and reconfigurations of human-computer relations - is under constant development. This accentuates the need for continuous reflection on how new materials, interaction styles and products challenge our theories, and in turn how theories can be employed to understand these new developments. Bridging concepts provide one way of facilitating this exchange by articulating the knowledge construct both in terms of its ties to theory

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and particular design exemplars. Specifically, we propose that bridging concepts are composed of three constituents: a theoretical grounding, a series of design articulations and a set of exemplars that embody the properties of the concept, reflecting the span from theory and practice.

In the following sections we begin by positioning and developing bridging concepts in relation to existing intermediary forms of knowledge that have been discussed in the CHI community. We then present the concept of 'peepholes' as an example of a bridging concept and analyse it in terms of theoretical grounding, design articulations and a selection of exemplars. We conclude the paper by providing two additional brief examples of established concepts that may be considered as bridging concepts, and then discuss more broadly the potentials and applications of bridging concepts.

We consider the main contributions of the paper to the CHI community to be 1) the presentation and discussion of bridging concepts, and 2) the development of peepholes as a particular instance of bridging concepts, including theoretical foundations, design articulations and exemplars from design practice. The intended audience for the paper is therefore researchers focusing on the development of the discourse on interaction design and HCI research and articulation of new forms of knowledge within this domain, as well as practitioners and researchers within the field of experience-oriented design.

## INTERMEDIARY FORMS OF KNOWLEDGE IN HCI

Recently, Höök and Löwgren [21] introduced the notion of 'strong concepts' as an intermediate-level knowledge construct in the space between theory and design particulars; the notion of strong concept was also the subject of a debate at CHI 2013. In their words, "Strong concepts are design elements abstracted beyond particular instances which have the potential to be appropriated by designers and researchers to extend their repertoires and enable new particular instantiations" [21 p. 5]. Strong concepts are thus specifically developed to occupy the middle ground by accounting for recurring phenomena in interaction design, and to offer a richer understanding of said phenomena by looking at their commonalities. As an example, the authors employ this approach to discuss 'social navigation' as a strong concept - a concept which can be found in a variety of different forms in existing systems and services, and which is now articulated on the basis of recurring aspects and qualities. This approach, which bears family resemblance to other knowledge constructs such as design patterns, can be said to be inductive, in that it draws from particulars to form a more generalizable concept. Höök and Löwgren consider their work on strong concepts to be an extension of Stolterman and Wiberg's [41] 'conceptual constructs', a wider definition of forms of knowledge that occupy this middle ground between theory and practice. In our view, Stolterman and Wiberg's conceptual constructs differ markedly from Höök and Löwgren's strong concepts in that "the point of departure is conceptual/theoretical rather than empirical" [41 p. 98] and in that Stolterman & Wiberg's objective is theoretical advancement, or in their words developing "innovative concepts that lead to intellectual development through definitions, conceptual constructs, and theories." [41 p. 112]. One example of such an innovative concept is the Dynabook [25], which was never developed as a final product, but has inspired a wide array of subsequent research.

Stolterman and Wiberg thus differ radically from Höök and Löwgren both in terms of the approach to developing intermediary forms of knowledge and the objectives for doing so: strong concepts are primarily developed bottom-up or inductively with the main purpose of generating knowledge that can be employed in design practice, whereas conceptual constructs are primarily developed top-down with the main purpose of enriching the theoretical foundations of HCI. In light of our argument for the need for concepts that can mediate between theory and practice, the two forms of knowledge represent opposite positions, which we seek to connect: The two sets of concepts serve different purposes for different audiences, in that strong concepts primarily support design practitioners in developing products, whereas conceptual constructs serve to help design researchers make theoretical advancements. This is an important distinction to make, both in regards to understanding where the concepts emerge from, how they can meaningfully be employed, and on which grounds they should be evaluated.

In a wider perspective, intermediary forms of knowledge can emerge from design research in several ways. In some instances, they emerge from examination of concepts informed and inspired by theory; in other cases, they emerge through developing specific cases and abstracting knowledge from them; and finally, they may emerge through both these processes concurrently. Koskinen et al. [26] conceive of 'Labs' as constructive design research approach in which theoretical concepts serves to inform and inspire the design of novel artefacts, which in turn come to embody the concept. Often several artefacts are created to examine the potential of the concept. Alexander's 'patterns' [1] also occupy a middle ground between practice and theory, but stand out from Labs since they are developed from recurring, successful examples in practice with the intent of supporting design practitioners in finding and combining well functioning patterns, which can be assembled and developed to form a new artefact. Zimmerman's 'framing constructs' [44] are similarly developed from recurring design patterns, but seek a stronger link to theory by examining how theory can be operationalized as part of the product, which in turn can also lead to new understandings about applying theory in design processes. Bowers' 'annotated portfolios' [2] present design cases and seek to abstract knowledge from them in order to create intermediary level knowledge, as design

practitioners simultaneously document and reflect upon connections between different examples of their work.

We do not consider one way of generating intermediary knowledge as being inherently better than the other ones - e.g. operationalizing theory through concepts [26] versus abstracting concepts from practice [1, 19, 44]; indeed, we consider both forms crucial to the development of the discourse on design research. It is in this light that we present and discuss bridging concepts as a particular form of intermediary knowledge.

## BRIDGING CONCEPTS AS A PARTICULAR FORM OF INTERMEDIARY KNOWLEDGE

Bridging concepts are a form of intermediary knowledge distinguished by their ability to facilitate exchange both ways between overarching theory and practice, rather than by being developed from theory or practice or with the specific aim of informing either theory or practice. As a knowledge construct, a bridging concept can be developed in any of the ways discussed above, and can support movement from theory to design and vice versa. Our motivation for introducing the notion of bridging concepts is primarily that it can shed light on how exchanges back and forth between overarching theory and practice can be facilitated.

In relation to the accounts of intermediary forms of knowledge outlined above, the concept thus stands out in that it can be developed from both theory and practice – often in a continuous process of theoretical and practice-based explorations, which is characteristic of many experimental design projects – and that it can subsequently be employed to both inform specific interaction design projects and to further develop theoretical understandings of the field of HCI. As such, bridging concepts are akin to Höök and Löwgren's strong concepts, in that they can be inspired by significant examples of existing installations, 'exemplars' in the terminology of Krippendorff [27], but stand out from strong concepts since they can simultaneously be developed from theory, rather than being predominantly abstracted from design practice. As such, the theoretically grounded development of a bridging concept is more in line with Stolterman and Wiberg's [41] conceptual constructs. However, it departs from the definition of the conceptual construct in that it is a generative concept also intended to inspire, inform and guide design practice, rather than one primarily focused on theoretical advancement. We have chosen to label this form of knowledge a bridging concept, since it is developed to bridge the gap from theory to interaction design practice. This does not mean that a bridging concept is detached from practice. Indeed, in our view it must be directed towards concrete issues in interaction design practice and should be evaluated on how well it ultimately helps us understand and act on these issues. A bridging concept can thus draw upon both existing exemplars from interaction design practice, as well as upon one or more strands of theory.

| | Conceptual constructs | Strong concepts | Bridging concepts |
|---|---|---|---|
| Primary origins | Theory | Design cases | Inspired by exemplars as well as theory |
| Primary intent | Theoretical advancements | Informing design practice | Facilitating exchange between theory and practice |

**Table 1: Comparison of the roots and objectives of conceptual constructs [41], strong concepts [21] and bridging concepts.**

Table 1 offers a rough overview of the departure points and objectives of conceptual constructs, strong concepts, and bridging concepts, respectively. There are nuances that escape this rough categorization. As an example, conceptual constructs may well contribute to design practice, even if that is not the primary intent; and strong concepts can be theoretically substantiated, even if developed from design cases. As such, both conceptual constructs and strong concepts can potentially be developed to serve as bridging concepts. We must stress that we do not consider bridging concepts to be a critique of conceptual constructs, strong concepts, or the other intermediary forms of knowledge outlined above. Rather, we consider it a complimentary form of knowledge residing in the space between theories and specific design instances; in the same vein, Höök and Löwgren [21] point out that other concepts such as design patterns and heuristics can also be considered part of this middle ground between theory and practice (Figure 1).

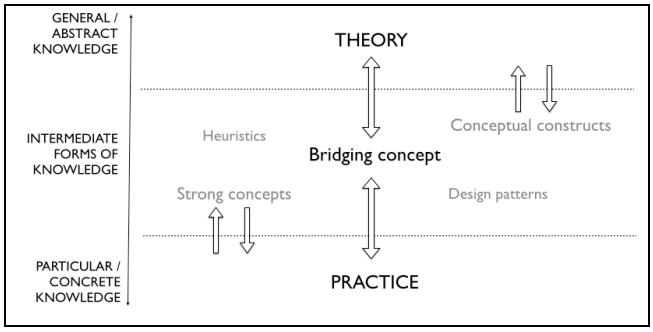


**Figure 1: Bridging concepts as one form of intermediary knowledge bridging between theory and practice.**

Summing up, a bridging concept has the following features:

- It inhabits the middle ground between theory and practice

- It is accountable to both practical exemplars, the parameters that shape the concept (articulations) and theoretical grounding.

- Its purpose is to bridge and span the gap between theory and practice and thereby unveiling and articulating untried design opportunities and potential theoretical advancements.

We propose that bridging concepts, in order to serve as bridges, are composed by three constituents which can help

interaction design practitioners and researchers understand their grounding and potential and offer advise on how to employ them in practice. First, bridging concepts have a theoretical grounding. In the case of the peepholes bridging concept, we draw primarily on pragmatism and philosophy of technology. Second, drawing on exemplars as well as theoretical insights, bridging concepts can be illuminated through the formulation of design articulations. Inspired by Krogh and Petersen [29], we use the term 'design articulations' to refer to the parameters that are important in expressing the qualities of a concept. Third, bridging concepts may be explored through exemplars that clearly illustrate critical aspects of the concept. Exemplars may illustrate similar salient aspects of a particular concept or may be critical in the sense that they delineate the boundaries of the concept.

## PEEPHOLES: A BRIDGING CONCEPT FOR UNDERSTANDING AND DEVELOPING ENGAGING INTERACTIONS

Having outlined the anatomy of bridging concepts in general, we will now present and discuss the notion of peepholes as a particular example of a bridging concept. In keeping with the properties of bridging concepts outlined above, we first explore a theoretical grounding of peepholes, which builds upon pragmatist philosophy. This constituent ties the intermediary concept to theory. Second, we explore design articulations for the concept of peepholes. By design articulations we refer to the salient parameters that designers can manipulate to change the interaction and experience of an artefact. We couple these articulations to the theoretical grounding. And third, using the design articulations, we analyse design exemplars that are critical in terms of showing the potential and scope of the concept of peepholes in terms of practice and theory. We have previously addressed the notion of peepholes in a design case study [11] and a preliminary discussion of the design of peephole installations [6]. Here we focus on peepholes as an example of a bridging concept.

By peepholes we refer to interactive artefacts that provide a limited view into a larges space. Peepholes play on the tension between what is hidden and what is revealed to spark engagement. In the physical world, keyholes or cracks in a fence provide the viewer with a limited view to a larger space and appeal to our inquisitive nature providing us with views into hidden, secret or even forbidden spaces. Within architecture and art, peepholes are well known as a means for enticing the curious viewer. Architects use light, acoustics and physical structures to suggest that the space holds places that are not immediately visible but can be found if people actively explore. From art and architecture to interaction design, the qualities of peepholes are no less attainable, as the malleable qualities emerging from the fusion between physical and digital materials provide designers with a broad palette of opportunities. Peepholes may be moveable, change size, provide clues of orientation and the universe to which they provide a glimpse may be changed and subject to interaction.

Within the CHI community, the notion of peepholes has been explored to some extent. Most often, peephole interaction is used as a means for providing views into large information spaces. As early as the 1990's, scholars at PARC explored the concept of portholes as means of supporting awareness in distributed work. Early efforts also explored portholes in the form of palmtop computer used to access information in ubiquitous computing environments [17]. More recently, several authors have used the similar concepts of peephole displays, peephole interaction or peephole pointing where studies have explored visualization and interaction techniques for providing users views of large information spaces (e.g. [24, 33, 38, 43]). In these studies, the peephole displays are most often realized using various handheld devices that are mapped onto larger surfaces or information spaces. Common to these contributions is a focus on providing users with an effective and manageable way of accessing large information spaces of various kinds. A notable exception is provided by Gaver et al. [19], who discuss the design and rationale behind the Drift Table – a coffee table with a small screen in the middle providing a moveable birds eye view of a map. The authors use the installation as a means for exploring how technology can support ludic engagement. This work most clearly resonates with our idea of the peepholes concept in this paper, in that it examines a particular form of interaction, which inspires the user to explore and discover the content of the installation. The concept of peepholes presented here is thus situated within the HCI discourse on user experience that reaches beyond usability and effectiveness exploring aesthetic, playful and engaging qualities of interaction (e.g. [31, 32, 37]). At a glance, the concept of peepholes appears similar to well-established HCI notions such as affordances in the sense of providing an invitation for people to interact. However, where affordances typically refer to qualities that clearly indicate to the user what she or he should do and what results will be achieved, peepholes have a more voyeuristic character. They provide enticements and play on the tension between what is hidden and what is revealed. Their virtue is the way they spark imagination about what is hidden beyond the immediate scope of our senses. This difference in perspective resonates with Overbeeke and Wensveen [36], who distinguish between affordances and 'irresistibles', stressing the qualities of attraction and temptation rather than functional perception.

### Theoretical grounding of peepholes

Our conception of peepholes builds on pragmatist philosophy, specifically the works of John Dewey. Dewey is considered one of the founding fathers of pragmatism and developed his position in an extensive range of books and papers from the 1880es to the 1950es. We primarily refer to

his later work on art, experience, inquiry, and technology [12, 13, 14, 15].

Pragmatist aesthetics have been a source of inspiration for several contributions to HCI, especially in the domain of experience-oriented aspects of interaction design. Among others, Forlizzi and Battarbee [18] developed their work on understanding experience in interactive systems on Dewey's conception of experience, Petersen et al. [37] drew on Dewey and contemporary pragmatist Richard Shusterman in their exploration of aesthetic interaction, and McCarthy and Wright's [32] work on technology as experience is developed from Dewey and Bakhtin. Our conception of peepholes is inspired by these works, as well as Dalsgaard's [5, 8, 9] notion of inquisitive use, which explores the Deweyan notion of conflict as a starting point for engaging experiences, a proposition that resonates with key characteristics of peepholes.

We draw upon five concepts from Deweyan pragmatism in our development of the peepholes concept, namely situatedness, conflict, inquiry, technology, and the intertwined nature of thinking and doing. Due to space constraints, we will only offer a rough outline of these concepts, focusing on the implications it has for the design, use and experience of interactive systems.

*Situatedness*

All human experience and action is inherently dependent on, and must be understood in relation to, the situations in which we find ourselves. According to Dewey, "we never experience nor form judgments about objects and events in isolation, but only in connection with a contextual whole." [16 p. 66-67]. If we wish to understand how a user will perceive of, and potentially interact with, an interactive system, we must consider not just the relation between user and system, but also the factors of the situation, including the physical space, socio-cultural aspects, other people, and other forms of physical objects and technologies, all of which may influence the user-system relation.

*Conflict*

Dewey proposes that conflict "stirs us to observation and memory. It instigates to invention. It shocks us out of sheep-like passivity, and sets us at noting and contriving. Not that it always effects this result; but that conflict is a sine qua non of reflection and ingenuity." [12 p. 207]. In other words, the perception of conflict or tension in a situation is what prompts us to investigate, seek new understandings, and potentially try to overcome the conflict. For designers of interactive systems, this presents conflict and tension as elements that may be employed to prompt action and reflection with users.

*Inquiry*

While many aspects of our lives are guided by routine, inquiry is the process by which we seek to alter a situation when a form of conflict arises. Inquiry is aimed a transforming or rearranging one or more elements of a situation so that it makes sense and/or resolves tensions. A person facing a conflict will often draw upon a range of resources at hand, including a variety of technologies and work with other people to change the situation so that the conflict is resolved. For the design of interactive systems, this prompts designers to consider both how the process of inquiry can be supported and which elements may be included in guided inquiries.

*Technology*

Most human activity is mediated by some form of technology. In a pragmatist perspective, technology has a dual nature in that it is both frames how our perception of the world and augments our potential for changing the world. For good or bad, technologies influences the way we make sense of our surroundings. Some technologies do this quite directly, e.g. sensors that make things visible to us. Others technologies do so less directly by inviting us to focus on the aspects in our surroundings that we can act on, hence the phrase "if all you have is a hammer, everything looks like a nail." This conception of technology invites designers of interactive systems to consider not only how a system may support specific actions, but also how it may frame the users sense making and perception of options.

*The intertwined nature of thinking and doing*

Deweyan pragmatism proposes that thinking and doing are tightly interwoven, to the extent that distinguishing between the two is at times untenable. We form thoughts and hypotheses in response to events in the world, and often with an intended action in mind; and we often start acting in the world because it helps us think and examine potential futures. Sketching is a well-known example of the intertwined nature of thinking and doing in interaction design. This conception prompts designers of interactive systems to consider how the interplay between action and reflection may be scaffolded in a system.

Taken together, these pragmatist concepts has informed our definition of peepholes as a bridging concept: Peepholes are interfaces that seek to engage users and invite them to explore the content of a system by creating a tension between what is hidden and what is revealed. They frame users' perception of the content by providing initially limited access to it, while also hinting at the potential for access by offering means for exploring that which is hidden from plain sight. Peepholes thus rely on elements of conflict to spur engagement and inquisitive use.

**Design articulations for peepholes**

Building upon the theoretical foundations of peepholes, we propose that there are a series of issues that are of particular salience to designers of peephole installations.

The design articulations presented here are all concerned with the interaction gestalt [30], i.e. the way in which the interaction unfolds between user and system. The

articulations serve to give an understanding of the parameters that give peepholes their particular qualities, and to prompt designers to put a particular effort into considering these aspects. It is for this reason that we address the dimensions as articulations, rather than e.g. heuristics or guidelines. In addition to being informed by theory, the articulations are also substantiated by our analysis of a range of peephole installations, three of which are outlined in the following section on peephole exemplars.

*Manoeuvring between hidden and revealed*

The central tension afforded by peepholes is the relationship between what is hidden and what is revealed. In the physical world, keyholes are fixed in their position and the scenery that they unveil is also typically stable. Interactive peephole installations must strike a balance between obscurity and revelation, and unlike static physical peepholes, this balance must be maintained throughout the user's interaction if the tension is to be intact. Thoughtful design of peephole interactions can both draw upon and support reciprocal processes of thinking and doing with users by striking the right balance. In some installations, a peephole strategy may be employed to attract people and subsequently be replaced by other means of engagement once users are drawn in, whereas other installations may maintain the peephole format throughout. Some peepholes have a fixed position and always provide a limited view into a particular world. Other peepholes however can be moved at the discretion of the user or may move automatically. Special consideration must be given to the potential for both framing the user's perception of the installation and offering means of altering it: How much is visible? How can the user manoeuvre and manipulate the viewpoint? How will further content be revealed through user input? An interactive system may provide a moveable peephole, whereas the scenery remains the same; or it present a fixed peephole while the scenery changes; or it may present dynamics in both peepholes and content. The manoeuvrability, then, can both be a quality of the peephole itself and of the scenery to which it provides a view.

*Navigational clues*

When there is a potential for interacting with a peephole, be it via dynamics in the peephole, the content, or both, designers must consider how they can provide navigational clues. The choice of navigational clues is an important one since is plays a major part in maintaining the tension between what is hidden and what is revealed. This can be a tricky affair and if navigational clues become extensive and the user consequently gains too much of an overview, the peephole looses its intrigue. On the other hand, too few navigational clues may leave the user frustrated to the extent that installation becomes unattractive.

*Sensory qualities and modalities*

In the physical world, peepholes are by definition visual. Interactive installations traditionally often rely on visual components as well, but they need not be limited to one sensory modality. They may involve more senses and/or forego the visual side entirely. To the extent that e.g. audio-based installations may draw upon the same tensions and strategies for intrigue and engagement as visually oriented installations, they may also be considered instances of peepholes. In many cases, designers may choose to combine different sensory modalities to promote user engagement. E.g. an installation may combine tangible and visual components (as is the case with *Tangible 3D Tabletop* which we shall return to). A combination of different sensory modalities can be used to reinforce a particular experience, and may also be employed to increase the tension by delivering intentionally contradictory messages, e.g. an audio track may invite the user to carry out certain actions, but the tangible and visual components can resist or delay user input so as to further up the stakes.

*Metaphors for prompting inquisitive use*

Analogue, physical peepholes embody a series of familiar affordances and constraints – we know what to expect from the peepholes themselves and to some extent we also know what to expect when we look through them. The same does not go for interactive peepholes, unless they quite directly mirror their analogue counterparts. Two important design decisions are therefore to determine how to present the peephole itself, and how to build up expectations about what can be experienced through it. One way of doing this is to create a metaphor that is familiar to users. This can establish an understanding of what to expect of the peephole as well as the content. However, as has been seen through the history of visual interfaces, users do not always correctly decipher metaphors, and incongruences between analogue and digital properties may cause metaphors to break down, potentially ruining the user experience. As is the case with combinations of different sensory modalities, designers can also intentionally use metaphors to build up expectations and then surprise users by breaking those expectations. The Out of Bounds installation [35] uses the metaphor of a flashlight, but when users shine the flashlight on a wall, they see through the wall into the next room.

**Peephole exemplars**

In order to demonstrate how the design articulations above may shape the qualities of peepholes, this section provides an analysis of five peephole installations. During our work on developing the concept of peepholes, we have identified a range of peephole installations, as well as taken part in the design of several. We have selected these five peephole installations because they illustrate how the concept may be employed across a range of use cases, and how different forms of interaction may support peephole interfaces.

*Hydroscopes and Drift Table*

The *Hydroscopes* installation, co-developed by the authors, was designed for a marine centre as part of an installation where visitors could construct their own fish using physical building blocks. The first part of the video accompanying this paper shows the Hydroscopes in use at the marine centre. Visitors could mix qualities from various species putting together different fins, bodies and heads to explore how various fish have different characteristics. Having constructed their fish, visitors could release them into a virtual ocean that was only visible in glimpse by pushing the Hydroscopes around the floor surface (figure 2). As visitors moved the hydroscopes, they could explore the fish created by other visitors.

**Figure 2: Children push a Hydroscope to explore a virtual ocean. See also the accompanying video for demonstration.**

The Hydroscopes employ a very direct metaphor, providing users the idea of life in the ocean being partially hidden beneath the surface, only visible through the Hydroscopes. The movement of the Hydroscopes is mapped directly onto the virtual ocean, so as to offer a clear navigational mapping between the peephole and the content. In terms of interaction, the Hydroscopes thus exemplify a peephole that is mobile in two dimensions. While the Hydroscopes are primarily visually oriented, small loudspeakers were imbedded in the casing providing an ocean soundscape.

The Hydroscopes resemble the aforementioned Drift Table (figure 3) in the sense of providing a limited visual view from above. In terms of interaction and metaphor they are however quite different. The Drift Table elegantly uses the weigh of everyday objects to steer the view. The metaphor is, by conscious choice, more ambiguous. While the view and the pace of the moving view may resemble a hot air balloon, the metaphor breaks down when using weights to change direction. Moreover, the view is scaled down in order to make the table more akin to a normal coffee table than a screen and also making navigation challenging. In terms of the attention to detail, the design of Drift Table reflects great care for supporting the experience of looking down at a landscape far below, using Fresnel lens to support the illusion of depth. Our point here is not to say that designers should opt for the most consistent metaphor, but to show how two relatively similar installations can be shaped very differently in terms of interaction qualities.

**Figure 3: The Drift Table offering a small peephole view.**

*Tangible 3D Blueprints and Jurascopes*

Tangible 3D Blueprints, an installation co-developed by the authors, combines tangible tabletop interaction with 3D projection in such a way that the tangible objects may be augmented with visual material corresponding to their physical shapes, positions, and orientation [7]. The second part of the video accompanying this paper shows the Tangible 3D Blueprints in use. A static two-dimensional floor plan is shown on the tabletop, and when a tangible is placed on the tabletop, it provides a three-dimensional view into a building (figure 4). This enables the user to examine aspects of the building that are not represented in the blueprint (e.g. height of walls), as well as enhancing some of those that are (e.g. textures and lighting).

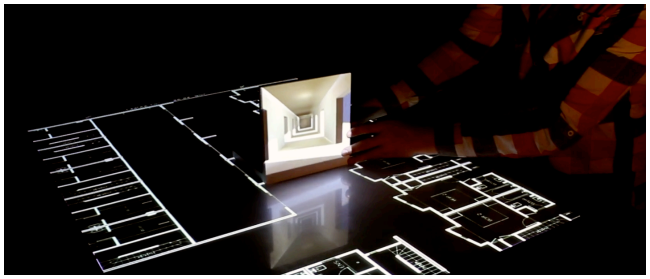

**Figure 4: Tangible 3D Blueprints use tangible interaction and visual feedback to offer a peephole into a building blueprint. See also the accompanying video for a demonstration.**

The Tangible 3D Blueprints installation is designed with the intent of offering users who are unfamiliar with engineering blueprints an alternative way of experiencing building plans so that they may contribute to co-design of future buildings. Contrary to the Hydroscopes, it provides very clear navigational clues in terms of the floor plan that provides clear bounds and orientation in the virtual building. While the tangible in itself does not build on a specific form of metaphor, the physical, spatial form in combination with the 2D blueprint provides an intuitive form of interaction and navigation.

The draw of the 3D tabletop is not so much that people wonder which room they are 'walking' into. Rather, the installation invites exploration by changing the sensory

qualities from two- to three-dimensional visuals and providing an alternative point of view, which contains enough novel information to prompt users to explore the different parts of the building. As such, it builds up tension with the intent of making users understand and interact with the proposed building plans. For the purpose of this paper, the installation serves the purpose of showing the scope of the peephole concept since it can be considered a means to an end, i.e. informed participation in a co-design event. In this respect it differs from most of the other peephole installations we discuss, which can be considered discrete and self-contained. An example of such an installation is *Jurascopes* from the Museum of Natural History in Berlin. The two installations are similar in the sense that navigation is straightforward. The Jurascopes, however, provide peepholes in time as the skeletons come to life and materialize in their natural surrounding (figure 5).

**Figur 5: Jurascopes use a binocular metaphor and offer a glimpse into the Jurassic era.**

*Listen Here!*

Moving on from two exemplars that primarily employ tangible and visual sensory modalities, there are also examples of installations that use audio as the basis for peepholes. Similar to the keyhole as an archetypical peephole, the practice of eavesdropping shares many of these qualities. The eavesdropper is provided an auditory glimpse of private conversation, and just as the keyhole, the access is restricted. An example of an auditory peephole is the Listen Here! concept by Nicola Hume [20]. Here, a map is synchronized to microphones placed around the city and people can explore sounds from around the city using a stethoscope (figure 6).

**Figure 6: Listen Here! [20] offers auditory peepholes to live audio streams from urban locations.**

Similar to the 3D tabletop, the Listen Here! concept is very clear in terms of navigational clues as red markers clearly indicate where microphones are placed. The combination of the stethoscope and the map is interesting as there are two layers to the installation. The stethoscope is a strong metaphor for listening to the sounds of a particular place, and at the same time, the map clearly indicates where to microphones are located. In a way, the red markers work as peepholes and the stethoscope is the device with which to access these. Contrary to the 3D tabletop and the Hydroscopes, the peepholes in the Listen Here! concept are not mobile. The user can move the stethoscope around the map but the peepholes remain in the same position. Rather the soundscape into which the user is provided a view is likely subject to change as people pass the microphones in the city.

## OTHER EXAMPLES OF BRIDGING CONCEPTS: PERCEPTUAL CROSSING AND AFFORDANCES

We have presented and discussed peepholes at some length in order to give a detailed example of a bridging concept. However, there is a range of other existing concepts, which we consider to embody the characteristics of bridging concepts. We will briefly mention two such concepts: 'perceptual crossing' from the work of Deckers [10] and 'affordances'.

Perceptual crossing refers to the phenomenon that one person's perception influences a co-present person's perception and vice versa. It is "the interplay of perceiving while being perceived (…) We share a common space in which we can build a history in the course of our interaction." [10 p. 7] We will classify this as a bridging concept, since a) it is rooted in theory, specifically phenomenology of perception and ecological psychology; b) it is illustrated by a range of exemplars and analyses of interactions; c) it is developed as a model, which in turn results in d) a series of design considerations that can guide design practice. While still a new concept, it is one that, in our view, holds the potential to both strengthen the theoretical understanding in HCI of an important aspect of how and why interactive systems are perceived and used, and offer guidance for designing systems in practice. It thus lives up to the bridging concept principle of accountability to both theory and practice.

Looking at a much more well-established concept, 'affordances' is arguable one of the best known terms in HCI. The debates and developments surrounding affordances in HCI illustrate the strength of concepts that facilitate exchanges between practice and theory. The concept is specific enough to have inspired designers in their work yet also has a strong theoretical basis. The theoretical aspects have been the subject of some debate since Norman [34] introduced the concept in HCI. Debates arose about the extent to which affordances as they were used in HCI did justice to their theoretical origins in ecological psychology, and later contributions have tried to further develop the concept with both strong ties in theory and potential for concrete application [3, 23]. The discourse on affordances in HCI have spanned almost three decades and provides a good example of how a bridging concept can

promote continuous exchange and prompt accountability both in terms of practical applicability and theoretical grounding.

## CONCLUSIONS AND FUTURE WORK

When Rogers [39] in 2004 took stock of the achievements in HCI research she stated that the field appeared to be in a state of flux; new theories where imported and developed and design practices and technologies where changing at an apparently ever increasing rate. While much has since been achieved within HCI, we appear to be facing roughly the same situation ten years on. While a highly dynamic field is arguably a desirable quality of HCI, it also challenges us to continuously explore the coherence and interplay between theory and practice. If connections between theory and practice are not maintained and re-articulated, the risk is a drift, where theoretical developments are made but these are out of sync with the object of study. Bridging concepts insist on articulating the connections between theory and practice through theoretical grounding, design articulations, and exemplars and thus promote accountability to both theory and practice. We find similar calls for alignment between theory and practice in the work of Stolterman [40].

Bridging concepts are inherently unstable constructs – perhaps best illustrated by the history of affordances in HCI. Obviously a bridging concept such as peepholes could be grounded in several theoretical positions apart from pragmatism; similarly, it can be informed through an evolving range of exemplars. Our point is thus not to seek a stable grounding of bridging concepts, but rather to show that they call for exploring different forms of grounding and articulation. This in turn can alter the exemplars and vice versa. It is exactly this process of grounding, re-grounding, articulation and re-articulation that facilitates exchanges and thus reflections on the ties between theory and practice. A bridging concepts, then, can have value beyond being a finalised form of knowledge, since the very process of creating and criticising bridging concepts within a research community is essential to its on-going development.

Looking more specifically at peepholes as a bridging concept this work has, for us, indicated untried design opportunities. As regards the sensory qualities and modalities of peepholes, our research indicates that most interactive peepholes rely primarily on visual modalities. In our survey we have not been able to find examples of installations that, for example, create taste or touch peepholes. This is arguably unsurprising, given the historical predominance of visual interfaces in HCI. However, we have strived to offer examples of how other modalities can supplement and/or replace visuals, such as embodied interaction with the Hydroscopes, the tangible interaction of Tangible 3D Blueprints and the auditory components of Listen Here! Explicating the concept of peepholes may motivate the exploration of examples of how different sense modalities can be employed to create peepholes.

Moving the other way across the bridge, the development of bridging concepts can also point towards inadequate theoretical foundations and potentials for 'importing', appropriating or developing new theoretical positions in HCI. In terms of importing or appropriating theoretical frameworks, our work on peepholes shows how pragmatist philosophy may be relevant for addressing specific aspects of engagement and inquiry in interaction. In terms of identifying underdeveloped theoretical positions, a concept such as 'touchpoints' in service design has enjoyed a large uptake in service design discourse, yet seems underdeveloped in terms of theoretical grounding. Developing the theoretical grounding could potentially make this concept a useful conceptual bridge between the theory and practice of service design.

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