USE, NON-USE, AND APPROPRIATION OF LARGE NON-INTERACTIVE

PUBLIC DISPLAYS IN HIGHER EDUCATION CONTEXTS

A Thesis

By

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Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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August 2017

Major Subject: Visualization

ABSTRACT

Large Display Technologies (LDTs) are becoming common in public spaces, changing the way we engage and share media content. The end use of LDTs can range from broadcasting information feeds (e.g., news programming) to supporting users in manipulating on-screen content (e.g., an interactive building map). One use residing as a mid-point of this range are non-interactive LDTs with content and interaction driven by users' own personal devices. LDTs of this type are associated with supportive furniture, connection ports, and the presence of network protocols. Potentially, users can carve out personalized activity spaces in public, allowing them to engage their digital content just as they would at home or at the office. We identify this specific use of LDTs as Publicly Appropriable LDTs (PALs). Stakeholders of PALs might understand what users need in regards to technology support and furniture, but may lack the means of evaluating the outcomes of said installation. Existing literature on LDTs do not provide frameworks on how PALs can support users' activities. To solve these issues, we need to better understand how PALs are situated in context with respect to users and its surrounding environment.

In this study, we conducted an evaluative study of a PAL installation at the College of Architecture (CoA) at Texas A&M University. The CoA's installation of PALs consists of a set of 8 individual units dispersed across the three floors of its main academic building. Users varying from students to faculty members were interviewed and observed as they utilized these PALs in their daily practice. From this study we found three categories of findings. First, we saw how users appropriated PALs specifically to their activities. Our second finding centered on how the PALs' displays transition in and out of active use

during occupation and what this signifies as its role during use. Finally, we found that the surroundings of a PAL had space and place-based attributes that impacted users' experience of PALs.

ACKNOWLEDGEMENTS

I would like to thank my committee chair, Dr.Quek, and my committee members, Dr.Chu, and Dr.Smith, for their guidance and support in this work. Thanks also goes to my friends and colleagues within the HCI@Viz lab and Department of Visualization. Finally, I want to thank my mother, father, brother, and sister for their patience and encouragement.

CONTRIBUTORS AND FUNDING SOURCES

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CHAPTER I

INTRODUCTION

I.1. Large Display Technologies (LDTs) in the Public

Large Display Technologies (LDT) are becoming common technology fixtures in public space, changing the way we share and engage with media content (Churchill, Nelson, Denoue, Helfman, & Murphy, 2004; Dix & Sas, 2008; Huang, Koster, & Borchers, 2008; Kuikkaniemi, Jacucci, Turpeinen, Hoggan, & Müller, 2011; Kuikkaniemi et al., 2014). They can be found in a variety of settings such as airport lobbies, train stations, shopping areas or work environments. LDTs take on the form of front and back projected wall displays, large flat displays, and smartboards.

LDTs are being installed in public spaces for two reasons. First are the advancements in the technology and connective capabilities of displays and content driving devices (R. E. Su & Bailey, 2005). Second, as LDT prices continually fall, the more cost-effective they are for the wider populace to obtain. Altogether, these events are enabling the wider inclusion of LDTs in real world deployments (Peltonen et al., 2008; Robertson et al., 2005; Vogel & Balakrishnan, 2004).

I.2. Continuum of LDT Use

LDT use may be organized along a continuum of varying levels of interactivity with digital content. On one end of the spectrum are non-interactive displays, where LDTs are used primarily as information displays. Examples of content displayed include advertisements, presentations, timetables, or television feeds (Brignull & Rogers, 2003). Non-interactive LDTs are thus used passively for displayed content and nothing more. On

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the other end of the continuum are interactive displays. Displays such as these enable users to manipulate displayed content. Examples of use includes juxtaposing different information content, keeping information persistent, or supporting presentations (R. E. Su & Bailey, 2005). This use can be characterized as dynamic in nature, in that experience of displayed content is unique to the user's actions.

One use of LDTs that is seeing growing development are semi-interactive displays made available in public spaces. Displays such as these reside in the middle of the LDT interactivity continuum. While the displays themselves are non-interactive, the burden of interaction is shifted over to user's own mobile device collections. An example of this LDT use are smartphone-driven content on LDTs, such as the kind seen in "MobiToss" (Scheible, Ojala, & Coulton, 2008) or "Ubi-Hotspot" (Ojala et al., 2010). Another example this kind of use is when LDTs have content driven by users' own personal computing devices. What is characterized by this form of use is the need for dedicated table spaces to support them. This is novel, in that it represents explicit public spaces that are freely appropriable for one's own digital activities (Müller, Alt, Michelis, & Schmidt, 2010). In terms of interest towards this work, we are concerned with the latter. We call this particular use "Publically Available LDTs" (PALs).

I.3. What PALs Afford Users

PALs can often be found in settings such as offices, libraries, or university hallways. The inclusion of PALs in such settings reflects an growing work trend in information work based contexts. Information work can now be engaged anywhere; provided that mobile technology and network protocols are supported (N. M. Su & Mark,

2008). The key benefit of this development is that digital information can be represented anywhere, untethered to any one given location (Ciolfi & De Carvalho, 2014). Ciolfi et al. argued that this development changes how information workers engage with their digital work. In this change, Ciolfi et al. likened information workers as nomadic pastoralists, on the move searching for resource settings that allow for their information work activities to take place, giving rise to the term, "nomadic work" (Ciolfi & De Carvalho, 2014).

I.4. How LDTs have been Studied in the HCI Literature

The overall topic of LDTs have been approached from various research angles. LDTs have been studied on how they deliver non-critical information to users (Huang et al., 2008). Work has been conducted on how LDTs can influence community and social activities (Brignull & Rogers, 2003). In terms of interaction design, questions of how to handle privacy and multiple user input have been investigated (Vogel & Balakrishnan, 2004; Wallace & Scott, 2008). LDTs have been empirically studied on how they are used in collaborative workspaces (R. E. Su & Bailey, 2005). While there are a variety of LDT research topics, the specific case of PALs has been overlooked. Despite this issue, PALs can be approached as a intersection between existing subtopics within the LDT literature.

I.5. Problems for Stakeholders

The lack of design guidelines for PAL installation is problematic for stakeholders of these supportive technology spaces. While stakeholders understand what kind of supportive furniture and technology infrastructure are needed, their implementation of a PAL may not align with how users might appropriate them (Luff & Heath, 1998). In addition, stakeholders assume that the displays alone are sufficient to attract attention or

encourage interaction (Huang et al., 2008). In reality, users are hesitant to interact with LDTs in terms of its time commitment or risk for social embarrassment (Ten Koppel, Bailly, Müller, & Walter, 2012). In the absence of guidelines, stakeholders cannot fully assess the outcomes of their implementation of a PAL.

I.6. Approach and Research Questions

In summary, there are two problems identified here; the first being of a practical nature and the second, one that stems from research. Practically, stakeholders lack a means of evaluating the outcomes of installing PALs. In terms of research, the LDT literature does not provide theories as to how PALs support information work.

One approach to this problem is to study existing PALs installation. In this approach, we assume the following. Given that each user is an embodied being, PALs ought to reflect the ways they practically interact with each other, their activities, and the surrounding environment. By taking this view we can understand issues that affect users PAL supported activities and experience of them. This can include how users readily appropriate PALs, how they disengage from them, or how environmental relationships can influence activity outcomes.

In pursuing this research interest, we conducted an evaluative study of a PAL installation at the College of Architecture (CoA) at Texas A&M. The CoA's installation of PALs consists of a set of 8 individual units dispersed across the three floors of its main academic building. The setting holds two noticeable attributes. First, the installation site hosts a variety of different potential user types in accordance to major, interest in using the PAL and role within the university. Second, the PAL units are each set in spaces that

suggest inter-personal dynamics unique for its location. Altogether, each unit is enmeshed within a different mix of users, activities, and dynamics with the environment.

I.7. Research Questions and Hypothesis

In pursuing this study, we formalize the following three research questions:

- *RQ 1: How well do users take advantage of and appropriate designed features of PALs?*

- *RQ 2: In what ways do users exhibit non-use of PALs' features?*

- *RQ 3: How do the PALs exist in terms of notions such as a space and place?*

We hypothesize that experiential differences in PAL use can be attributed to two factors. First, how an PAL is used is dependent upon it's occupants' scope of activity. Second, is how the environment's physical and social dynamics influences PAL mediated activity.

I.8. Thesis Organization

The thesis organized as follows. First, **Chapter II** reviews topics relevant to PALs within the wider LDT literature. Next, **Chapter III** describes the theoretical concepts used in framing the study's scope. **Chapter IV** details the study context and its actors. **Chapter V** recounts methods used in collecting data. Following afterwards, **Chapter VI** states the data analysis procedures. **Chapter VII** illustrates the key findings of the study organized thematically. **Chapter VIII** generalizes the results to the wider literature. **Chapter XI** considers the significance of the results and its limitations within the study. Finally, **Chapter X** discusses the future direction of work following from this study.

CHAPTER II

LITERATURE REVIEW

The existing PAL literature has focused recently on understanding the dynamics of LDTs when made "publically" available. Existing work within this topic area has focused on issues spanning the delivery of non-critical information to users (Huang et al., 2008), establishing privacy (Vogel & Balakrishnan, 2004), enabling community and social activities (Brignull & Rogers, 2003), understanding motivation of use (Ten Koppel et al., 2012), supporting collaborative (Rogers & Lindley, 2004), or asynchronous interaction (Peltonen et al., 2008). One gap identified within the literature is the intersection of issues such as collaboration, appropriability, and the place-making of PALs in the support of work activities. We believe that the little work in this area can be attributed to the timeliness of this topic. This is due to the how LDTs have reached a point of technical maturity and economic feasibility to be integrated in public settings.

Despite the little work concerning this specific area, work does exist tangentially concerning PALs. We identified three categories of issues that are related to PALs:

- Configuration Traits

- Means of Interaction

- Forms of Activity

In filling this gap, our first step is to identify the elements that make up this intersection. We will present existing work in the following headings: 1. Configuration Attributes of PALs; 2. PAL Mediated Interaction; and, 3. Kinds of PAL Supported Activities.

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II.1. PAL Configuration Attributes:

A PAL's physical attributes such as its positioning or viewing angle can impact its occupants' task performance and experience of activity. This subsection summarizes research pertaining to PAL's physical configuration attributes. These are categorized in two groups: 'Display Orientation' and 'Display Location'.

II.1.1. Display Orientation

How a display is oriented can have outcomes on users experience the displayed content. This has implications for both active users of the display (e.g., users occupying a PAL) and those peripherally aware of it (e.g., individuals passing by within view).

Most users experience of an LDT is from passing it by on route to their own activities. While users can be aware of the display's presence, this alone is not suffice to encourage engagement. Getting users to notice or motivate activity with interactive public displays is a common issue within the LDT literature. Ten Koppel et al. argued that linked multiple displays can better encourage user interaction than single displays (Ten Koppel et al., 2012). In their study, they compared three different configurations of linked interactive displays within a public walk space of a university canteen. In these displays, users can play a motion sensitive game while passersby can look on. Between the three configurations, they noted different passerby outcomes as framed from an actor-audience relationship:

- **'Flat':** 'Flat' configurations consist of two or more attached displays that are oriented towards the same direction. This configuration saw more instances of actor-audience interactions. In addition, 'Flat' also

accommodated for more simultaneous users than the other configurations. Ten Koppel et al. suggest that 'Flat' afforded higher visibility of actions and consequently social learning for co-situated viewers.

- **'Hexagonal':** 'Hexagonal' configurations consist of six attached displays oriented away from one another. In this configuration, current occupants are separated from one another with respect to visibility of on screen activities. However, occupants can observe the physical actions of other users in their peripheral view. The configuration had the effect of separating audience members into different groups. After a while, audience members eventually stabilize towards one of the six displays to maintain group cohesion.

- **'Concave':** The 'Concave' configuration positions the angle of linked displays towards a common viewing point. This configuration could only allow for up to two users to comfortably use the displays. The limitation created a physical separation of present individuals into an interacting group and observing group. Because the observing group tended to view the active users from a distance, this had the effect of reducing interaction between these two groups.

Even when users are directly interacting with an LDT, due consideration is needed in its orientation. How an LDT is oriented with respect to a user's viewing angle can delineate how they can perceive and interact with the display. Rogers and Lindley investigated how displays supported activity differed between vertically and horizontally

oriented LDTs. In their study, they focused on the collaborative and social affordances that were unique to each form factor (Rogers & Lindley, 2004). From their two studies, they found that horizontal and vertical LDTs hold the following affordances for users:

- **'Horizontal':** The horizontal orientation afforded group members cohesion in their displayed activities. First, physically present users can refer to the same displayed content during discussion. Second, during group use, users can easily transition between physical document creation and digital information access activities. Third, the physical surface enabled users to exchange the role of content presenter during discussion.

- **'Vertical':** Vertical display collaboration was limited in terms of simultaneous users. This limitation came from the limited space that users could occupy to interact with the display. One advantage for vertical orientation was that more users can view content than the horizontal orientation. Essentially, the vertical orientation afforded support for information presentation.

Similar to Roger and Lindley, Su and Bailey (R. E. Su & Bailey, 2005) studied how differences in multiple LDT configurations can influence user experience outcomes. In their study, participants performed application window movement tasks across two connected LDTs. Participants performed these tasks in different linked LDT configurations. Differences in task outcomes were tested among configuration attributes such as display-to-display distance, angle between displays, and symmetry of displays. Su and Bailey's findings suggest that changes in configuration attributes can affect user's subjective workload, time expenditure, or satisfaction. Specific to display orientation,

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users can tolerate a visual angle of 45 degrees in gaps between linked displays. However, should the visual angle go beyond 45 degrees, users will turn their heads to maintain a cohesive view of the linked displays. This could cause users to develop neck strain when using the display for prolonged use.

II.1.2. Display Location

The location of an LDT can play a part in both users awareness and engagement of it. Location of an LDT can consider its placement within the surrounding environment. The user's personal space can also be considered.

Different areas of the environment are often designated a purpose. Where a LDT is located in these areas can frame the interaction possibilities that users can engage in. Dix and Sas (Dix & Sas, 2008) suggest that screen placement can affect how individuals perceive its availability of use or 'publicness'. From their review of the LDT design space, Dix and Sas identified the different ways that LDTs can vary in 'publicness':

- **'Fully Public':** Displays of this type are found in places such as city centers or airports. In terms of access, anyone within physical reach can access it.

- **'Semi-Public':** Displays of this category are found in places such as the corridors of outside offices. While the displays can be physically accessed, they are set in places that are limited to individuals who have reason for being there.

- **'Semi-Private':** This category refers to displays set in closed off environments such as faculty offices. Access to these displays is limited by those who can enter these environments legitimately.

Location can also be understood in terms of a user's activity space. Where a display is located relative to a user can influence how they can engage the displayed contents and one another. Plaue and Stasko (Plaue & Stasko, 2009) investigated how the location of a shared display can affect collaborative work performance. In their study, Plaue and Stasko compared collaborative use across shared display configurations. Single displays, side-by-side displays, and opposing shared displays were studied. From their study, Plaue and Stasko yielded the following findings:

I.   Users were able to establish more inferential links between displayed contents with the "side-by-side" shared display configuration versus the "opposing end table display" configuration.

II.   User groups noted that there was a benefit to having the two shared displays situated side by side when performing their task. The benefit was attributed to the display's affordance for supporting data comparison and exploration activities.

III.   The "side-by-side" shared display, was found conducive to the supporting social interaction with users versus the other configurations studied.

II.1.3. Summary

A PAL's installation hold properties that affect its occupant's experience and activities. The placement of a PAL can determine what kind of physical actions that users can engage in while occupying them. The user's orientation to an PAL can influence how they can view and interact with displayed content.

II.2. Motivating Users to Interact with Public LDTs

The issue of encouraging users to interact with displays is a problem unique to PALs. Users are often hesitant to interact with PALs due to the visibility of their actions or lack of familiarity with its design. In order to motivate users to engage PALs especially it is important for the design to be sensitive to these concerns.

While a PAL can have the capabilities necessary for content sharing or information access, use of these capabilities are limited by what users consider appropriate use within context. Motivation to use a PAL can be supported if its design is framed within the context's conception of appropriate use. Churchill et al. studied how large displays are used for content sharing in communal settings (Churchill et al., 2004). They conducted their study at a research center, observing how its users adopted their 'Plasma Poster' system in daily practice. Plasma Poster is an interactive PAL that allows users to share and author content on it. The system was studied for 14 months in order to observe how usage patterns evolve over time. From their study, they suggest that its use was supported by some of the following factors:

- **'Technology':** Churchill et al. describe Plasma Posters as centered around the high-level goal of 'information sharing'. They imposed no specific vision of the kind of appropriate use or the kind of content to be displayed. Instead, these specifics were evolved over time through the community that used it. Users posted content ranging from business news items (new products, technology related), humor (cartoons, jokes), general news (weather, local area news),

announcements (conference talks) and project specific information (press coverage on FXPAL projects).

- **'Personalities and Activities':** The studied organization, FXPAL, was said to consist of individuals that were inherently curious and information sharing was a major aspect of their work identity. Here, Churchill et al. suggest that the lack of a clear appropriate use for the Plasma Posters, allowed this study population to appropriate the displays to support this aspect of this organization.

- **'Organizational Culture':** Churchill et al. also looked at the study population as a cultural unit. They described FXPAL as an organization that was tolerant to new technologies, information sharing, and the informal practices that arise out of this interaction. This concept was manifested in the few restrictions placed on kinds of content on the Plasma Posters. Here, what we can gain from this is that the organizational culture of a PAL setting can serve to frame the range of appropriate use of activity.

Motivation in using displays can be dependent upon how users view ownership of the PAL. One key difference between private and public LDTs is how the concept of ownership plays in interaction. Private ownership enables users to freely explore the capabilities of an LDT without the burden of social embarrassment and the benefit of time to invest in it. This is not the case with public LDTs, where one's actions are highly visible and availability is not assured. Huang et al. studied how to better design PALs with respect to in-situ motivation [14]. They studied how shared displays can be integrated into real world working environments. They examined the challenges associated with the adoption

and integration of NASA's MERBoard within a real-world deployment setting. From their study they noted three determinants to the success to which such displays can be fully integrated into a workplace:

i. **"Users must be able to perceive the system as valuable":** Huang et al. described that users generally need to experiment with new technologies in order to get a feel of what it might offer them in their work activities. The effort expended in learning a new system, maybe subject to whether or not they feel a sense of ownership to the shared display.

ii. Huang et al. found that users needed to have some sense of permission and ownership in order to readily use the LDT. In the absence of this connection, users are less likely to devote time and effort to include the LDT in their workflow.

iii. **"Users must perceive the system as easy to use":** Huang et al noted that the "ease of use" of the system was subject to two factors. First, users want to understand what level of effort is needed to integrate the display with their own mobile computing devices. Second, users determine "ease of use" from the level of effort needed in accessing the displays (e.g., "Because shared large displays are regarded as a group resource and generally reside in shared workspace as opposed to personal space, users may be less amenable to spending time learning how to interact with them;").

iv. **"Users must perceive the system as available when they need it":** The extent to which the MERBoard can be appropriated was dependent upon two

factors. First, users want to know when exactly MERBoards were available so they can rely upon it when needed. Second, should MERBoard be in indirect use (e.g., other individuals viewing the screensaver for site-wide news), users need to know how feasible it is negotiate for personal use.

The decision to engage a PAL can be thought of as existing on a continuum form awareness to direct engagement. Brignull and Rogers describe a model that illustrates how one's engagement is coupled with their relative location to the display and decision process that convinces them to move closer towards it. Brignull and Rogers [5] sought to understand what encourages individuals to use PALs. Within this topic, they focused on how PALs attracted initial attention. In addition, they also studied how perceived risk for social embarrassment discouraged PAL use. From their two studies on their prototype display, 'Opinionizer', they identified two key findings:

- **'Vicarious Learning':** Users learn how to interact with the display by observing the actions of current occupants.

- **'Activity Spaces':** Brignull and Rogers noted that there was a division of activity spaces surrounding the display during use. Each activity space afforded individuals different forms of involvement with the display. The users' activities were grouped in to three categories. The first, 'Peripheral Awareness Activities', refers to being peripherally aware of the display's presence and activity, but lacking knowledge of what is going on with respect to content. Users in this activity space could be engaging in activities unrelated to the display (e.g., socializing nearby). The second,

'*Focal Awareness Activities'*, refers to any activity where the display is the subject of user's attention. Here, users interact with the display by either talking about it, gesturing towards it, or viewing its content while occupied by another user. The third, '*Direct Interaction Activities*', refer to cases when the display's content is actively manipulated by a single user or group of users. Users transition among activity spaces based on their understanding of what the display cost them in time expenditure needed, benefit of interaction, or the ability to disengage without disturbing ongoing activity.

II.2.1. Summary

The work described here suggests that PALs are appropriated based on the user's understanding of what PAL affords them in their activity. The decision to appropriate a PAL is subject to perceived factors such as time expenditure, effort in use, or risk for social embarrassment. Users come to understand a PAL's affordance through its design model, attitudes from its cultural context, or through observing other's use of it.

II.3. Kinds of LDT Supported User Activity

Users appropriate LDTs for two types of activities. LDTs can support display oriented activities such as working in multi windowed applications or for collaborative review. LDTs can also act as a support for discussion or presentation. Research concerning this topic is covered in this subsection.

II.3.1. LDTs Used for Information Display and Access

LDTs, when publically situated, are installed to aid in information dissemination. When LDTs of this type are made interactive, it is necessary to understand what kind of information can be displayed and how it can be acted upon.

One common use of LDTs is for supporting group activities such as discussion meetings. One example of such use of an LDTs is Jurmu et al.'s study on a PAL installed in a university meeting space. Jurmu et al. (Jurmu, Goncalves, Riekki, & Ojala, 2014) investigated how PALs can extend existing communication channels in dedicated community spaces. Using their 'Kupla' display system, they investigated how students appropriated the displays in their community. Relevant findings grouped under the theme of "Extensions of Communication" demonstrated the display's affordance for its user's communication practices:

i. **'Common Reference':** This refers to how the display was used as visual reference during meetings. When in use, students would place documents on the display in order to center the attention of physically present peers.

ii. **'Persistent Notification':** The display was used for the purpose of retaining information for future use between meeting sessions. One example of use includes leaving an assignment's information and associated deadlines up after a meeting.

Beyond supporting multiple users, LDTs can also provide a work benefit to single users. Czerwinski et al (Czerwinski et al., 2003) sought to understand the productivity benefits associated with using large displays for common computing tasks. Within their

study, Czerwinski et al. compared the performance outcomes between two display types. The first display was a standard display of 15-inches. The second display was a custom designed wide display of 42 inches. In their study, each participant carried out a series of tasks involving visual search, information retrieval, and data analysis. While performing this task, they were asked to retain memory specific to the original task. Two key findings from their study include:

 i. The large display saw a less time consumed when completing tasks. There was a significant performance improvement in completing tasks when measured by time.

 ii. The large display was noted to be difficult to use when the number of onscreen windows increased as activity went on. They believed the issue came from the GUI's interaction design failing to scale with the larger screen's resolution. The consequence of this issue is the time consumed in rearranging and resizing said windows.

Regardless if the PAL activity is based around single or multiple users, the activity engaged in a PAL is often based around the displayed content. The content displayed can vary with respect to how its connected to the immediate environment. Dix and Sas (Dix & Sas, 2008) , noted the different kinds of relationships that LDTs' displayed content held with the surrounding environment. They provided different categories that illustrate how displays are coupled to its surroundings:

- **'Coupling[sic]':** Displays such as these merely show unrelated content to the location such as a news feed.

- **'Weak Coupling':** These are displays that show information related to the wider area but not to the specific location the display is installed. An example of this could be an airport screen displaying schedules for different terminals.

- **'Close Coupling':** These displays have content that is related to the location it is installed. For example, a display could show content specific to an office within a building (e.g., display shows a professor's schedule).

- **'Dynamic Coupling':** These displays dynamically change in relation to the context of the environment, such as a display reacting to passing cars.

II.3.2. LDTs Supporting Social and Communal Activities

Beyond acting as a means of viewing or accessing information, LDTs can be employed to support social interaction between co-present individuals. LDTs can support user collaboration through by means of its wide viewing angle and space to accommodate multiple users.

The extent to which a PAL can support social interactions among its users depends upon the context it is based in. Wallace and Stacy (Wallace & Scott, 2008) described how the social and cultural context of a large display can influence group behavior. The behavioral norms can be subject to factors such as the relationship between group members, the organizational culture (i.e., social mores can impact the formality of personal interactions), or even the size of the group. Wallace and Stacy suggested that the table's physical form needs to account for how user engage one another. An example of this concern could be how the seating space between individuals matches up with a given culture's understanding of personal space.

User-to-display interactions are not limited to those who are directly engaged in PAL mediated activities. Instead it can exist in a range of engagement dependent upon one's proximity or awareness of the PAL. Dix and Sas (Dix & Sas, 2008) noted that users hold different relationships with the displays, based on their passive or active use of it. In characterizing these relationships, they drew a parallel to urban artistic performances in terms of the various roles that users can be in (Performers, participants, and bystanders.) Their formal categorization scheme for user to public display interaction include:

- **'Unwitting Participant':** Users may be interacting with display by sensor without noticing it.

- **'Participant':** User is actively engaged with the display.

- **'Unwitting Bystander':** User may view display but not aware of interaction.

- **'Witting Bystander':** User sees an interaction occurring.

- **'Passer-by':** User is aware of screen, but does not interact with it.

PALs can facilitate social interaction between physically present users in public settings. Peltonen et al. (Peltonen et al., 2008) reported on how public displays can be variably used. The studied display, 'City Wall', demonstrated support for different forms of group activities. Examples of activity include teamwork activities ("grouping with other users and focusing on the same object or set of objects") or parallel activities ("people can occupy an area of the screen and focus on their own task irrespective of the activities on their left or right."). In addition, the study showed how different social roles arise out of group display use. An example pointed out by Peltonen et al. is the "teacher-apprentice"

role. In this role, users more familiar with the display guide other users on how to interact with the display.

Social activity in PALs can arise not only during direct engagement but also by the awareness of the users surrounding the PAL's space. Brignull and Rogers (Brignull & Rogers, 2003) noted a social affordance associated with publically available displays, this being what they termed the 'Honey Pot effect'. The 'Honey Pot' effect refers to scenarios where individuals gradually come to surround a PAL due to the presence of other people. The presence of individuals surrounding the display provides a tacit signal to passersby that a novel event occurring. They came to this conclusion, noting their observations of the frequency of conversations about the display and interactions between neighbors within the space. They found that users positioned themselves around the space, based on notions of relevance to their activities, novelty, costs involved in its use, and consideration of what social mores are related to its use.

LDTs broadly support information access and interaction as a user defined activity. Within this base case, one can think of the scope of user activity as primarily focused towards displayed content with a single user driving its process. Within group use scenarios, the LDTs serves the purpose of persisting content as attention is shifted among members, devices, and the LDT itself.

II.3.3. Summary

PALs support user's activities in two aspects. First, PALs enable users to display digital information. PALs used in this case are used for supporting information distribution

for community or for presentation. Second, PALs enable users to interact with displayed content, either for access or for editing.

II.4. Summary

This chapter provided a limited overview of PALs. Prior work in PALs suggests there are three aspects regarding installation outcomes. First, the PAL's location can dictate the physicality of user's activity such as the extent for bodily action or the user's viewing angle of displayed content. Second, users' motivation to using PALs is influenced by their existing mental models, cultural context, and observing how PALs are used by others. Third, PALs support user activity by supplying a means of interaction and access to digital content.

CHAPTER III

THEORETICAL LENS OF ANALYSIS

Chapter II of the thesis demonstrated that PALs are not merely passive technologies installed in the public space. Instead, PALs are a form of supportive technology whose usage is influenced by the environment where it is installed, users' models of thinking, and overall purpose of use.

These factors altogether can refer to how PAL's are used to support the embodied activity around it (Dourish, 2004) . Embodiment refers to the intrinsic relationships in how we interact with physical and cultural entities within any given context. In HCI, the notion of embodiment is applied in the perspective of embodied interaction. Embodied interaction assumes that interactive devices are embedded in the very same physical and social reality of which its users reside. Beyond this understanding, the perspective emphasizes the dynamic relationship posed between individuals, artifacts, and context. Altogether, how an interactive artifact is attuned to human capabilities is dependent upon how its design model can support the embodied relationships around it.

Given this intrinsic set of relationships, it is necessary to have the appropriate set of theories to guide our study of said relationships. This chapter describes the set of existing theories that will inform our analysis within this study. Section III.1 describes existing HCI theories on how users appropriate interactive artifacts and disengage from them. Section III.2 describes Dourish's application of space and place within the HCI research context.

III.1. Appropriation and Non-Use of Interactive Artifacts

'Appropriation' and 'non-use' are elements of practice that influences how interactive artifacts are used differentially across users. These two concepts are described in the following subsections.

III.1.1. 'Appropriation'

The concept of appropriation refers to actions users take to adapt an artifact to support their individualized activities (Carroll, Howard, Vetere, Peck, & Murphy, 2001; Dix, 2007; Jurmu et al., 2014). Often times, appropriation can take place as users become accustomed to an interactive artifact's capability. The end result of this acclimation are the ways artifacts are repurposed beyond its original design intent.

Dix offered four reasons why appropriation of technology is to the benefit of the end user (Dix, 2007). First, appropriation allows for the adaptation of a device to the specifics of a given setting. Second, appropriation allows users to adapt said device as demands within the context changes temporally. Third, appropriation gives users a sense of control by allowing them to structure activity as they see fit. Finally, appropriation allows users to subvert the design model of the artifact, allowing them to improve or extend the artifact's function when the situation demands.

III.1.1.1. Relevance of Appropriation in Research and Design

Appropriation, as used in research and design, is used to reflect on how exactly users incorporate technology within their practice (Dix, 2007; Jurmu et al., 2014). By focusing on this element of practice, designers can understand how their designs will be reshaped during use (Carroll et al., 2001).

Dix addressed the question of how to design for appropriation in interactive technology. While it may be unlikely to design for the unexpected, Dix suggests that designers can still accommodate in the final design nonetheless. Guidelines from Dix's work that are relevant to this work are described as follows:

- *'Provide Visibility'*: Dix suggested that systems ought to visibly communicate what it can do so users can be certain in what actions they can take.

- *'Support Not Control':* Dix suggested that a system should support users in their activity but not take over the process thereof. This is appropriate for situations where the activity is incomplete and approximate in nature.

- *'Plugability and Configuration'*: Dix discussed the idea of 'plugability and configuration', reflecting on how users can customize systems from existing component systems.

III.1.1.2. Perspectives on Appropriation

Within the literature, appropriation can be looked at from three different perspectives.

First, appropriation can refer to the extent an interactive artifact's end use differs from the artifact's own design model (Dix, 2007) (Jurmu et al., 2014). Appropriation in this fashion arise from improvisation (e.g., "Using a screwdriver to open a paint tin".). Another instance appropriation of this kind occurs is when the alternative tool may involve less effort than traditional means (e.g., "…using email for sharing files instead of configuring shared network folders.").

Second, appropriation can consider how an existing artifact is modified to serve the user's end goals for an activity (Carroll et al., 2001). Appropriation can come out of adaptation of technology when no available tool exists (e.g., "…users mailing themselves a web link because bookmarks and email folders are distinct and they want to organize them together.". Essentially, when an present artifact fails to fully support the end goals of a user's activity, they may change certain aspects of its current design to better suit it.

Third, appropriation can be understood how users themselves adapt to an existing interactive artifact (Carroll et al., 2001). Carol et al. explain their understanding of how young people adopt and use interactive computing technologies in their Technology Appropriation Model (TAM). The model describes how technology is gradually explored, evaluated and subsequently adopted or rejected. The model consists of three parts, as seen in figure 1.
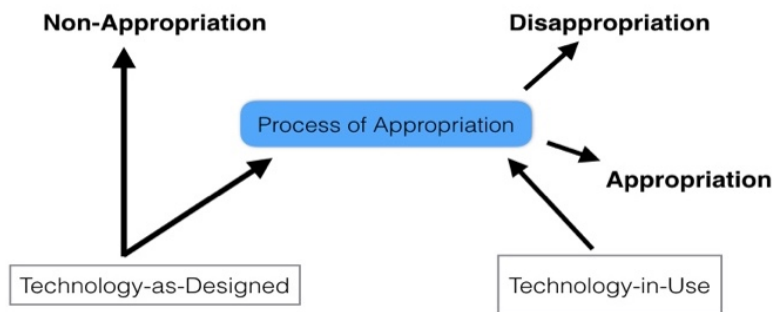
Figure 1. Carol et al. Technology Appropriation Model

First, 'Technology-as-Designed', refers to when an interactive technology is supplied to users. Next, 'Process of Appropriation', describes how users react to the design

of an existing implementation. Here, users either begin the process of appropriating the design in their practice or outright reject it. Finally, 'Technology-In-Use' is the case of when an interactive technology artifact evaluated and adapted into the users' everyday practices. During this stage, the artifact has become mundane; effectively stabilized in its use and understanding. However, use of the artifact is hardly static; the continued use of said artifact is subject to interactions between "…knowledge, needs, social interaction, time or the technology…" available. The end result of this continual re-negotiation is that technology can remain static, adapted, or disappropriated.

III.1.2. 'Non-Use' in HCI Literature

Non-use is a concept that focuses broadly on the deliberate decision to disengage from technology or technology mediated services (Oudshoorn & Pinch, 2003; Rice & Katz, 2003; Sambasivan, Ventä, Mäntyjärvi, Isomursu, & Häkkilä, 2009). Non-use within HCI is thought of as involving choice by the user and is episodic as use and non-use take place while a user engages with an artifact.

Sambasivan et al. demonstrated in their study how users can disengage from device ensembles in daily practice. From their study, two relevant themes are described here:

- **"Avoidance by the User":** This theme focuses on the user's reasoning for disengaging from devices. Broadly, users disengage from devices for the purpose to divert their attention to their physical surroundings (e.g., other people and artifacts). Non-use of this fashion can occur when users want to maintain focus on their activity and set their phone to silent.

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- **"Resistance to Forceful Devices":** This form on non-use refers to cases when devices are deemed intrusive or unwelcome at any given time by the user. This idea of device intrusiveness is subject to contextual factors such as if the device is shared, location of activity, access model, or organizational culture. One example of this type could be powering down a laptop when it is possible for others to observe one's activity in public spaces.

III.2. The Notion of 'Space' and 'Place' in HCI

Given the fact that computing technologies have become common place in public non-fixed settings; it was necessary to understand how the inclusion of these technologies may fare in supporting user activity. The notion of space and place have been used to analyze how to adapt technology in such settings.

Space and Place are notions transplanted from architecture into HCI for the purpose of understanding how organize action and interaction in digitally represented spaces (Harrison & Dourish, 1996). Space refers to the geometrical arrangements of a given site which can either structure, constrain, or enable action and interaction. Place differs where the same geometrical arrangements are supplied social meanings that guides action and interaction.

In the following subsections, these two concepts are detailed further.

III.2.1. *'Space'*

Space is a notion that is used to describe how the physicality of a location such as its structure, topology or orientation can influence individuals' actions and interaction with one another.

Space is evident in how we arrange our frequently used artifacts nearby for access and less frequented artifacts in dedicated locations (e.g., Desk documents versus documents set in a file cabinet.). Space can also refer to how the environment can be structured to afford specific outcomes (e.g., The co-location of faculty offices in the same space to foster collaboration.).

Harrison and Dourish (Harrison & Dourish, 1996) noted that there are attributes of space that can be used to support collaborative digital activity:

- '**Relational Orientation and Reciprocity**': This theme recognizes the shared experience and understanding of the same spatial organization of the world. One example is how the concept of "down" and "up" is the same for everyone. Through this consensus, we can properly interpret other's actions and behave accordingly to them (e.g., P1 asks P2 to grab the book on the upper left side of the shelf.).

- **'Proximity and Action':** This attribute refers to how our activity is subject to how far it can span from an immediate location. This notion manifests in how we take hold of objects closest, we adjust our speech volume depending on how far we are from others, we move closer to things to look at them in better detail.

- **'Partitioning':** This attribute highlights how individuals recognize how their actions how activity falls off within distance. Because of this limitation, this distance can be used delineate a separation between activities and interaction possibilities.

- **'Presence and Awareness':** This attribute recognizes how we coordinate our actions with the actions of others and facilitate interaction. Specifically, this refers to how we can structure activity simultaneously in the same space or seamlessly integrate our activities together.

III.2.2. 'Place'

Harrison and Dix argued that the affordance for appropriate behavioral framing comes not from the space of a given location but rather its status as a place(Harrison & Dourish, 1996). They define a place as " … a space which is invested with understandings of behavioral appropriateness, cultural expectations…". Akin to space, Harrison and Dourish identify properties that place holds:

- **"Place and Behavioral Framing":** This property refers to how users moderate behavior based on the culturally understood purpose of the current inhabited place. While places such as dance theaters and conference halls may share similar features such as lighting or orientation, each area is understood culturally of what is appropriate within its given place (e.g., " you wouldn't use the theatre are a space for presenting a paper and vice versa").

- **"Place is in Space":** Places are built out of the exiting geometric space. While activities can be dictated as suggested by space, how one acts within a place is governed not by these same properties, but rather by one's own cultural understanding of the place. Essentially, individuals moderate their behavior by what is deemed appropriate or necessary for a given place. (e.g., Different floors of the library have places set for quiet or for group study.).

- **"Place in Social Analysis":** In addition to behavior being framed by the defined meaning of a given place, it is also governed by the presence of others within the space as well.

- **"Place in the Built Environment":** Harrison and Dourish suggest that "placeness" can be measured in terms of the extent to which it either reinforces the norms of its context or defines it.

III.3. Summary

This chapter presented relevant theoretical works for framing our analysis for this thesis. The works presented here serve to highlight PAL's embodied aspects. In concluding this chapter, we leave off with operationalized definitions of the theories covered here for this thesis' work:

- **Appropriation:** Refers to user initiated activity on an existing artifact that results in either the user adapting to its design model, extending the artifact's design model, or modification of the artifact's current design.

- **Non-Use:** Refers to the user mandated disengagement of an interactive artifact for the purpose of diverting attention elsewhere or when the artifact in question is inappropriate for the current context.

- **Space:** Refers to how the physical attributes of the physical space can influence how a user can interact with an artifact.

- **Place:** Refers to how the culturally understood norms of a spatial setting can influence how a user interacts with an artifact.

CHAPTER IV

COLLEGE OF ARCHITECTURE STUDY CONTEXT

This chapter describes the CoA as the study setting. Section 1, Rationale for CoA as a Study Context, describes the CoA as an institutional entity. Section 2, Characteristics of the Studied Population, describes the study population and their academic interests. Section 3, CoA Instantiation of LDT, details the technical attributes of the CoA's LDTs. Finally, Section 4, Specific Instantiation of CoA LDTs, illustrates how the individual LDT units are installed across the building site.

IV.1. Rationale for CoA as Study Context

In order to understand how PALs support user's activities, the CoA was chosen as the study setting. Our rationale for the CoA as a study setting was based on three factors.

The first attribute was the how the CoA installed the individual PAL units. During the fall school year of 2015, the CoA installed a set of PAL units across three floors of its main building. The building itself consists of four floors, each providing a different mix of space usage. The first floor holds a life drawing studio, architectural design studio, café, and faculty offices. Next, the second floor is characterized by a walkway that separates its architectural library, administrative offices, and gallery in two spaces. The third floor contains studio spaces and faculty offices affiliated with the Department of Landscape and Urban Planning. Finally, the fourth floor, is set similarly to the third floor differing only in its affiliation, this being the Department of Architecture. The CoA installed PAL units across the second, third, and fourth floors of this building. Given the CoA's use of space

and the kind of activities the PAL's support, we saw this installation as an opportunity to understand how PALs are appropriated daily.

The second reason refers to the College's recent efforts (as of the summer of 2015) to redesign its main building into a supportive learning environment. We believe that the CoA's efforts are reflecting broader trends in learning space design. Brown and Long (Brown & Long, 2006) identify these trends as:

- "Design based on learning principles, resulting in intentional support for social and active learning strategies."
- "An emphasis on human centered design."
- "Increasing ownership of diverse devices that enrich learning"

The CoA's own diverse population was the third factor. While the CoA is defined by its historical precedent for architectural study, its houses 4 distinct departments administering 16 different degree programs. Each degree program specializes in different issues that informs the theory, conceptualization, practice, development, and management of building design. What this means for our study is that we can use these differences to study the relationship of features to user types.

IV.2. Characteristics of the Studied Population

Through the course of our study, we identified recurring patrons of the PAL units. These include the groups, Architecture (ARCH), Construction Science (COSC), Landscape and Urban Planning (LAUP), and Visualization (VIZA). Given the fact that the CoA is an open access building, it was accessible to individuals not associated with

any of the CoA Departments. Out of this group, we've identified Computer Science (CSCE) affiliated users and miscellaneous users (MISC).

ARCH is based on the practice of architectural design following a studio education model based around projects comparable to the professional field ("Undergraduate The Bachelor of Environmental Design Program,"). LAUP is focuses on the development of functional and sustainable human environments through urban planning and land development ("Landscape Architecture and Urban Planning Programs at Texas A&M,"). COSC is an interdisciplinary program that approaches the construction process by integrating the principles of architecture, technology, engineering, business, and project management ("Construction Science Program at Texas A&M University,"). Finally, VIZA's curriculum addresses the range of artistic, scientific, and technical issues based in the creation of visual experiences in film or interactive applications ("Visualization Program at Texas A&M University,").

Beyond academic focus, the population can be further divided based on role; this includes undergraduate students, graduate students, and faculty members. Undergraduates were the primary users of PALs with graduate students following afterwards. Faculty members rarely used the PAL units.

A commonality shared between these disparate groups are team-based ideation activities. Activities such as these serve as the core of the learning experience afforded to both undergraduate and graduate students across all units. Example work tasks for students in the College include completing a cost-estimation assignment, configuring mobile

hospital units, articulating architecture blueprints, designing sustainable parks, fabricating a digital prototype or animating a virtual creature for a short film.

IV.3. Specific Instantiation of Collaborative LDTs within CoA

Each PAL installation serves as a learning space support. The collective design of the installations takes into consideration how students may congregate around it and the kinds of devices that may be present. Each installation consists of three major components, these being the LDT, the table and associated chairs, and a HDMI based switcher system (Figure 2). The following subsections details these components further.
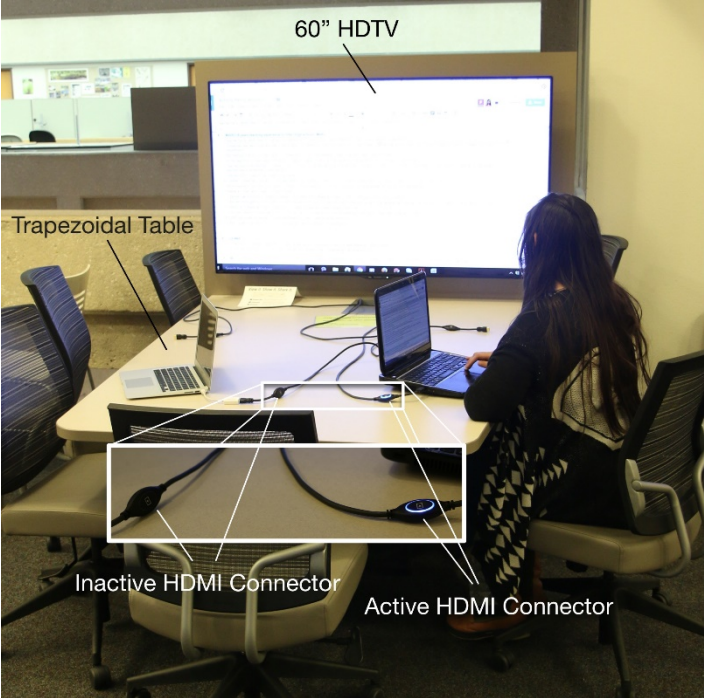
Figure 2. CoA's PAL Installation

IV.3.1. Describing the Display Component

The display component in each PAL was implemented as a 60" HDTV capable of displaying content up to 1080p resolution. The display possessed no control interface outside of the physical buttons for 'power', 'channel', 'volume', and 'input'. One noted capability was that the display could accept video content from any Bluetooth enabled digital device such as a laptop or tablet. This feature was not advertised immediately to users.

IV.3.2. Describing the Furniture Component

The furniture component of each PAL consists of a long work table. The table can accommodate to five individuals alongside their personal belongings. The table itself has a trapezoidal shape with a shorter edge distal away from the display (see figure 2). Within the table resides a recessed space hidden by a sliding panel that houses the HDMI switcher system and four power plugs.

IV.3.3. Describing the HDMI Switch Component

The HDMI switcher system consists of four custom HDMI cables, each possessing a button to change displayed content on the LDT to the controlling device's video source. When the button is pressed, the connector becomes active, and video and audio from that connector is pushed to the screen (see blown-up illustration in figure 2). The video switching is instantaneous, circumventing the need to switch the HDMI input selection on the HDTV. By using this system, users can change input content without having to physically pass a HDMI cable among other users.

IV.3.4. Instructions on Use

The CoA made no formal announcement regarding the operation of PALs. Instead, instruction for use was made explicit by a small attached cardboard sign placed on the
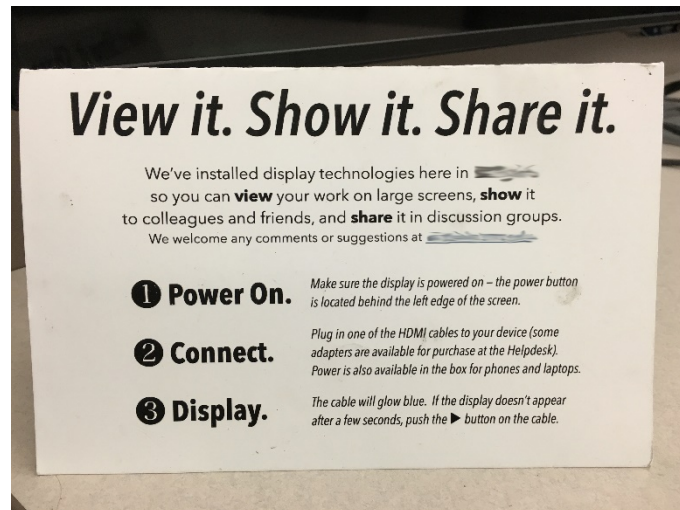
Figure 3. Placed Instruction Card for Each PAL Unit

table space. The small sign served two purposes. First, to invite users to use them for either their solo or collaborative work activities. Second, to describe the 3-step process of how to use the display (see figure 3).

IV.4. Specific Instantiation of Collaborative LDTs within CoA

The eight PAL units was distributed across the second, third, and fourth floors of the main CoA building (see figure 4). Each PAL unit was situated back-to-back (The case for the second floor), a wall, or balcony. Each PAL unit's environment exhibited varying levels of Dix's concept of public availability, as covered back in chapter II (Dix & Sas, 2008).

The second floor housed both PAL units, "PAL-1" and "PAL-2". Both units are located across from the Office of the Dean and to the right of the Office of Student Services (see figure 5). This location is characterized by its high level of foot traffic in regard to the college's population. A wide variety of users across major, role, or affiliation could access these two PAL units. Given these characteristics, this space can be characterized as being 'public' in its nature.
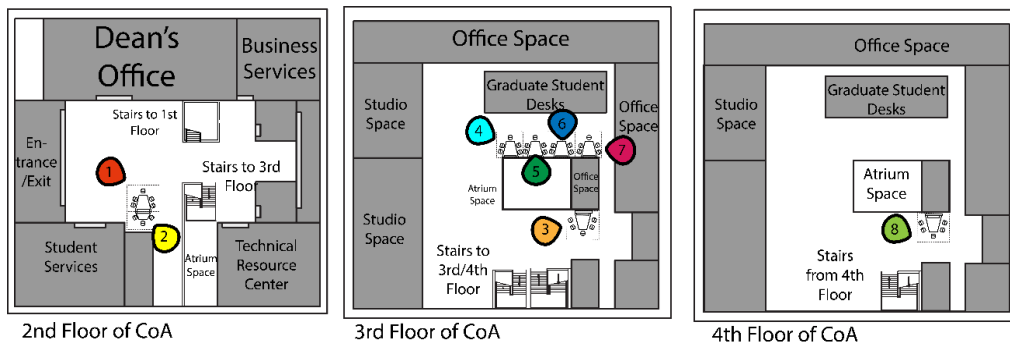
Figure 4. Map of PAL Units Across the Three Floors of the CoA Complex
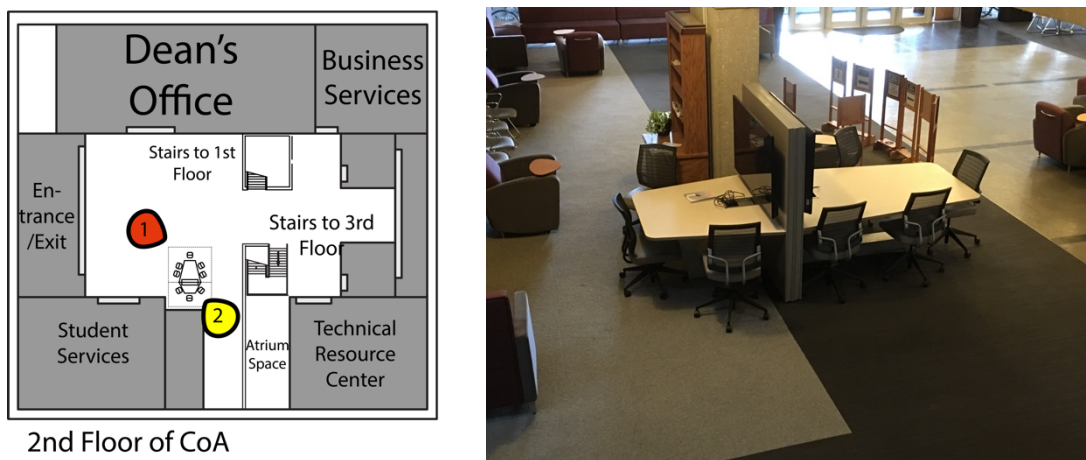
Figure 5. Second floor's PALs, 'PAL-1' and 'PAL-2'.

The third floor housed its PALs in two different settings (see figure 6). "PAL-3", was set in a location adjacent to the walking path between classrooms and faculty offices (see figure 8). Also of note, "PAL-3" was set nearby the stairway connecting the fourth and third floor. Similar to the units on the second floor, this unit can be thought of as being 'public'. The other PAL units, these being units '4' through '7', were situated within the LAUP graduate student open office space (see figure 7). These supportive LDTs were reserved for class use during the working hours of the main CoA building, otherwise they were subject to free use by its user population. The PALs noted here represent a variable case of 'publicness'. During certain times of the day, the units can be characterized as being 'semi-public' in that while the units are physically accessible by a wider audience, only those within its situated space can use it (i.e., having class.). Outside of time schedule, the displays are used by a wider audience after hours, changing its status to a 'public' availability.

The final PAL, unit '8', is situated on the fourth floor. Its installation is similar to that of unit '3' differing where the adjacent faculty offices are associated with the Department of ARCH (see figure 9).
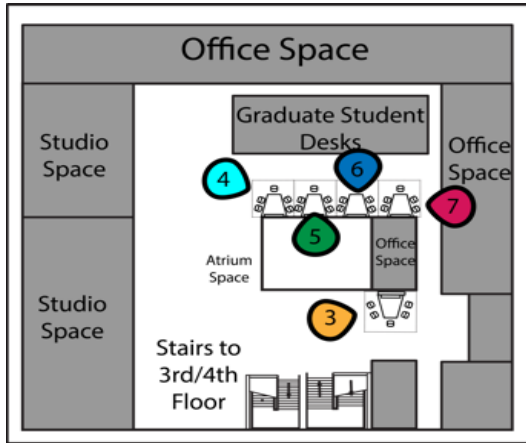
3rd Floor of CoA

Figure 6. Third floor PAL units

Figure 7. Third floor's PALs, 'PAL-4', 'PAL-5', 'PAL-6', and 'PAL-7'.

Figure 8. Third floor's PAL, 'PAL-3'.
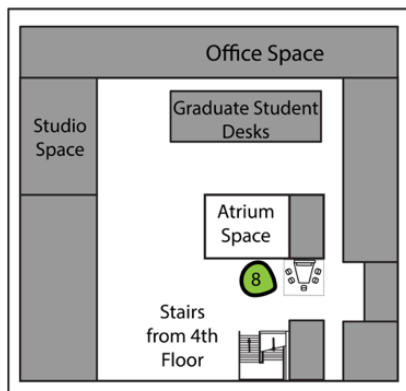
4th Floor of CoA
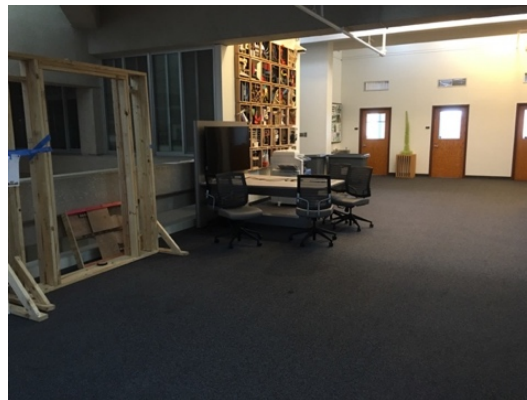
Figure 9. The fourth floor's PAL, 'PAL-8'. in CoA.

IV.5. Summary

This chapter describes the CoA's LDT installation as an exemplar for public use. The CoA as an institutional entity demonstrates an active interest in the use of digital technology in supporting its users work activities. Within the CoA, it hosts a variety of user types across academic classification, major, role within the university, and activities engaged. Attributes of the CoA's PALs were described, considering both its specific design and installation variations across the building site.

CHAPTER V

STUDY DESCRIPTION

This chapter describes the study procedures used in recording user's interactions with the CoA's PALs. To understand how the PALs supported user's activities, it was necessary to observe how the PALs were used in context. We used two approaches in our study. First, we interviewed PAL users to account for their thoughts and experience in the learning spaces. Second, we conducted observations of PAL use to better understand how appropriation contrasts among users. The chapter is organized as follows. First, section V.1 Interview Study, describes the recruitment and methodology used during interviews. Afterwards; section, V.2 Observation Study, details the procedures in observing users of PALs and note taking protocol.

V.1. Interview Study

Interviews were conducted to assess how users appropriated PALs for their activities. We first describe the recruitment process for obtaining participants and then describe our methodology for data collection. All study procedures produced were approved by the university Institutional Review Board (IRB) prior to the start of the study.

V.1.1. Recruitment Protocol

During the interview portion of the study, researchers recruited participants when occupying a PAL unit. Owing to the 24-7 access to the CoA building, it was possible to recruit participants during both working and after hours. Participants were recruited on the basis if they were interacting with any PAL unit at the time. We defined interaction as any activity supported by either the PAL's table space or digital display.

This could refer the different usage cases shown in figure 10. In 'A', it demonstrates the case where the LDT portion of the PAL was used in the presence of multiple users. 'B' provides a case where the LDT was the subject of all present user's gaze. 'C' shows how the PAL was used for its space alone. 'D' illustrates when the PAL is occupied by a sole user. Altogether, usage can range among these different forms.

When an instance of PAL use was found, a researcher approached the PAL's current occupants. Current PAL users were given with a verbal invitation to participate in an interview. Should users express informal interest, the researcher obtained their formal consent by using the IRB-approved information sheet and consent form. The form informs potential participants that the study will be audio recorded (IRB 2015-0559).
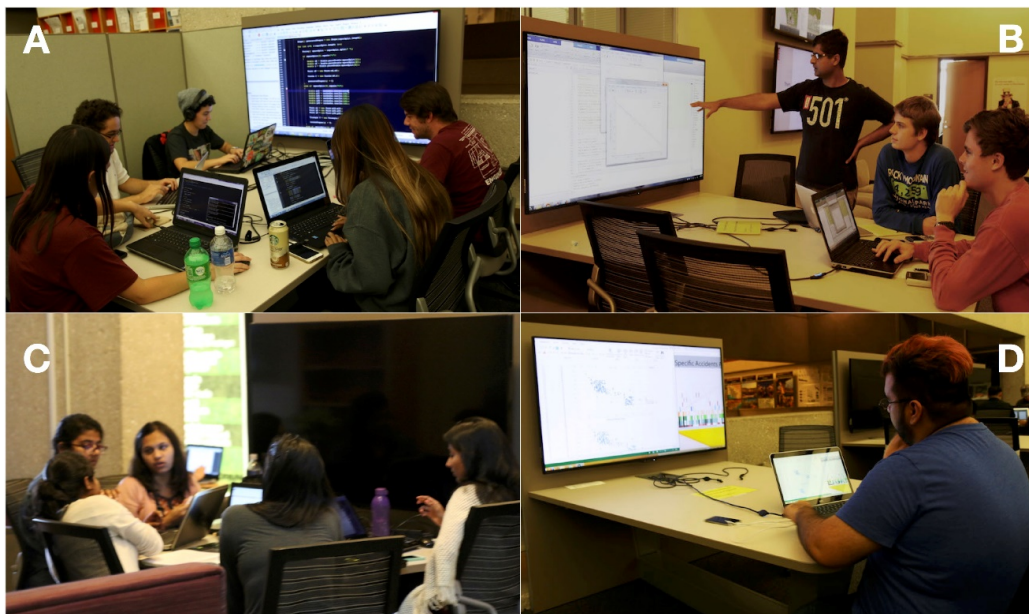
Figure 20. Different forms of PAL use.

V.1.2. Interview Study Protocol

Upon receiving written consent, the present research staff member commenced with the study. The interview script used by the researcher pertained to themes as noted in table 1. We use a 'semi-structured' approach for our interview format. The 'semi-structured' format allows a researcher to deviate from an existing set of questions, should the interviewee's response demands further elaboration. If there were multiple PAL occupants present, the interview was conducted as a group.

Interviews were conducted either as single interviews or as group interviews when the PAL was occupied by multiple users. Across the 17 interviews conducted, a total of 36 PAL users participated A total of 2 hours and 50 minutes of interview data was recorded, with interviews lasting between 5 to 16 minutes (averaging about 10 minutes).

Category	Description	Sample Questions
Decision Making'	What users believe are the purpose of the PAL units.	What do you believe was the reason that the collaborative spaces were set as they are right now? Why do you believe that the particular display and
Impetus'	These questions are concerned with why the PALs were installed.	What do you believe was the impetus that lead to inclusion of collaborative furniture within the college? What do you believe is the reason that the collaborative
Execution'	These questions are concerned with how the PALs are used and established.	What are some ways you would use the collaborative space? What encourages you to use the collaborative
Practice	These questions are concerned with how the display technologies have affected the day to day proceedings of acting members.	Do you believe that the collaborative spaces are set in appropriate places for faculty and students? Do you see the set of collaborative furniture enhancing any
Perception	These questions are concerned with how others may use PALs.	What do you believe was the reason the administration installed the collaborative
Impediments	What challenges did users face when using a PAL?	What were some issues that were endemic to the

Table 1. Interview Question Themes

V.2. Observation Study

Observations were conducted to detail further the specifics on how users interacted with the PALs. The observations were conducted as follows.

V.2.1. Observation Schedule

The observation portion of the study was performed at the CoA between the hours of 10 am to 4 pm. While the PALs are available continuously every day of the week, we chose this time range to account for activities representative of daily working hours. In addition, this schedule was informed by informal observations that noted the time when the supportive LDTs were most actively used.

V.2.2. Selection Procedure

For the observation portion of the study, it followed a similar protocol for the selection of participants. Researchers would find cases of PAL occupation, regardless of how it was used at the time. Observations were conducted until the current PAL occupants left the space. Afterwards, researchers moved to another occupied PAL unit for further observation cases. If the current observation went beyond the allotted 2-hour period, the session was extended until the PAL's occupants leave the observed PAL.

V.2.3. Observation Methodology

A 'disguised observation' methodology (Sullivan, 2001) was assumed when conducting this portion of the study. This method was chosen in order to avoid influencing PAL user's behaviors. Upon identifying a PAL in use to observe, the researchers positioned themselves in a close-by location to observe the PAL user(s)'s activities and screen displays.

After the researchers situated themselves in the environment, they began to take written notes of observed activities in the present PAL unit. At the start of a session, each researcher first described the layout of the observed scene. Elements of the scene that were included individuals present, personal belongings, and devices employed in activity. Afterwards, notes recorded details such as physical actions (e.g., gestures, body movements, facial expressions and gaze.), content displayed, display configurations, speech utterances, and hardware interaction. Notes were continuously written until the user(s) left the observation scene. Notes were written in 2 to 3 minute intervals. While notes were written, no interpretation of the recorded events took place.

A total of 12 observation sessions were carried out in total (35 users total.). With respect to observer count, 5 had 1 observer and 7 had 2 observers. Observations were conducted over a total of 13 hours and 27 minutes (2 hours each day over 4 consecutive days.).

CHAPTER VI

DATA ANALYSIS

This chapter describes how data was organized and subsequently analyzed. Data was analyzed using both qualitative and quantitative methods; the procedures are described as follows. In section V1.1, Interview Data Analysis, describes how interview data was transcribed and coded. In section VI.2, Observation Data Analysis, proceeds in a similar fashion.

VI.1. Interview Data Analysis

Interview data underwent two key processes. Data were first transcribed. Afterwards, the data were analyzed by means of qualitative coding.

VI.1.1. Transcription

During transcription, the researcher listened to audio data and typed out its contents verbatim. InqScribe (Inquirium) transcription software was used for this step.

VI.1.2. Qualitative Coding

Qualitative coding refers to the classification of raw data into different conceptual categories. For our study, we used this approach for three reasons (Sullivan, 2001). First, qualitative coding reduces raw data by identifying elements as specific codes, giving them a descriptive handle. Second, codes and coding schemes can be used to form conceptually higher level categories. Third, the approach supports the development of theory from generated categories.

VI.1.3. Coding Process

After the audio data was transcribed, the resultant document was transferred into MaxQDA (GmbH) to commence with qualitative coding analysis. In the following subsections, each step of the qualitative coding process is detailed.

VI.1.3.1. Open Coding

In the first stage of analysis, open-coding was used to apply descriptive labels to noteworthy items present within the text data. Low level codes described items, events, or concepts latent within the data. Descriptive and in-vivo codings were applied to generate first-level codes (Sullivan, 2001). These codings plainly described "low-level" activity and entities free from interpretation using either a short description phrase or the participant's own words. Examples of first-level codes were 'Screen size', 'The display is simple to set up', and 'Using display to look at plans' (see table 2).

1st Level Coding (Descriptive and In-Vivo Coding)	2nd Level Coding (Focused Coding)	3rd Level Coding (Axial Coding)
"Yeah we're both working on this kind of taking turns doing different things", "We are able to switch content between the computers","We are able to switch content between screen better", "Switch between screens", "Anybody can switch and put there screen"	*Switching Content Between Computers on Display*	Displays
"Because of table orientation", "Eveyrone can look at the screen", "You have a big screen so you don't need to move around", "Screen Size", "Large Screen", "First Impression is that TVs are huge", "Users can see display from all angles"	*TV Physical Attributes*	
"It is easy to plug machines in", "I always need to bring a connector for my machine to use","Can't cnnect laptop because of no HDMI connector", "It is simply to hook up HDMI to input", "Can put it in and start working on it", "I had to figure out how to turn on the HDMI cord"	*Understanding How to Use The HDMI Cable*	

Table 2. Example of Levels of Qualitative Coding for Interview Data

VI.1.3.2. Focused Coding

After identifying low-level codes, the generated codes were reorganized in accordance to higher level categories. The categories that were used were based on how frequently an idea or entity appeared in the existing codes. This coding approach was done by comparing the first-level codes in terms of similarity or repetition of ideas to develop salient categories. For example, if codes were frequently seen pertaining to the subject of

display connection, the latter would then be made into a second-level code, 'Switching Content Between Computers on Display' (table 2).

VI.1.3.3. Axial Coding

During axial coding, generated categories were interrelated on different PAL related issues. Categories that were generated from interviews spanned matters concerning the physical and technical attributes of the displays, specific configurations of use, user types, content displayed, and relationships to the surrounding environment. For example, if we look at the focused codes, 'Switching Content Between Computers on Display', 'TV Physical Attributes', and 'Understanding How to Use The HDMI Cable' (table 2), we notice that there are shared themes among them. Together, we can say that these codes describe either the features of the display or the practice of using one. Because the codes' relationship are limited to describing the display, we categorize these codes under the axial code, 'Displays'.

The axial codes are organized in terms of broader categories as illustrated in table 3. In addition, descriptive and inferential counts were derived from these generated categories.

VI.2. Observation Data Analysis

Following each observation session, collected data underwent two stages of process. This subsection describes the process as follows.

VI.2.1. Transcription of Written Notes

In the first step of the process, observation notes were comparatively reviewed between observers. After discussion, the notes were synthesized into a single textual document.

Axial Codes	High Level Categories
Displays', 'Personal Devices', 'Outlets', 'Technology Requests'	Describing the Technology Space
Getting Acclimated to Space','Users', 'Learning How to Use Space By Example of Other's Use','Permission','Space's Effect on Studio Culture','Frequency of Use', 'Space Can Be Used By Multiple People at the Same Time', ...	Describing Use Profile
Presence of Other People in Area', 'Open Building Environment', 'Building Environment Ambient Sound'	Describing the Building Environment
Furniture Requests', 'Table Usage', 'Table Shape Enables Interaction Between Team Members'	Describing the Furniture Space
Space is Easily Accessible', 'Simliar Spaces on Campus', 'Request for Spaces', 'Can Gather Around Space', 'Space Enables Interaction with Passersby', 'Spaces are Out in the Open'	Describing the Space

Table 3. Generated Axial Codes and Associated High Level Categories for Interview Data

VI.2.2. Qualitative Coding

After document creation, the synthesized note document was then transferred into MaxQDA to undergo qualitative coding. Two separate but related analyses were conducted with the observation data.

VI.2.2.1. First Analysis

The first analysis used a similar approach as the interview analysis, generating first-level, second-level and third-level codes (table 4 and 5).

The categories generated from observation data included for example, 'Technology Space' (types of technology used, specific configurations of devices, type of content displayed, and actions mediated by technology), 'Users' (user types, physical actions performed by users, number of users), and 'Purpose' (Reasons for occupying space around display).

VI.2.2.2. Second Analysis

The second analysis of the observation data was based on a summative content analysis approach. Summative content analysis involves "identifying and quantifying certain words or content in text with the purpose of understanding the contextual use of the words or content" but also with a latent process of interpretation of the content (Hsieh & Shannon, 2005).

From the analysis of the observation transcripts, counts were done of the first and second-level codes that related to three issues:

- Problems pertaining to display use and missed opportunities of display use;

- Instances involving passers-by observing, leaving, and types of interactions that they engaged with users;

- Display use variables, including user types, number of users, number of displayed elements, physical interactions, device types, connection types, content, and display mediated actions.

Axial Codes	High Level Categories
Outlets', 'Table is Used to Hold Belongings', 'Users are able to set asside space for belongings', 'Shape of table encourages users to be close'	'Table Space'
User is Interacting with Personal Artifacts', 'User Walks up to Space', 'User is looking/showing/gazing', 'User is pointing/gesturing', 'User is conversing with others in space', 'User leaving the space/putting away belongings'	'User Actions'
Describing Technology Used', 'Technology Confiurations', 'Content', 'Actions Related to Technology'	'Technology Space'
User Types', 'Quanity of Users'	'Users'
User is using large display for a report', 'Using the space for collaboration', 'Programming Assignment'	'Purpose for Occupying Space'

Table 4. Generated Axial Codes and Associated High Level Categories for Observation Data

Categories	High Level Categories
Connection Issue', 'Dead Display Time', 'Had to Stand up to Display', 'Looking at Other's Laptop Display'	**Observed Problems**
Passerby Observes', 'Passerby Leaves', 'Passerby Joins Users', 'Types of Interaction with Users', ,'Instance of Passerby Interaction'	**Passerby Variables**
User Types', 'Quantity of Users', 'Quantity of Displayed Elements', 'Physical Interaction with Display', 'Number of Devices', 'Types of Devices', 'Laptop-Device Relationship', 'Content on Display', 'Actions Performed with Display',Instance of Display Use', 'Instance of Potential Display Use'	**Display Use Variables**

Table 5. Results Following Summative Content Analysis

CHAPTER VII

RESULTS AND FINDINGS

We begin with an overview of our findings. Our data analysis uncovered several factors that influence how PALs support users in their activity. We found that general PAL usage was subject to both users' traits and the environmental context. First, user traits such as academic standing or field of study, frames the users' activity type engaged in PALs. Second, the PAL's location influenced what kind of occupant-to-passerby interactions can take place.

In this chapter, we will present our results on how PAL user characteristics and location can influence PAL mediated activities. The organization for each subsection is described as follows. First, in section VII.1, Describing PAL User Traits, we identify the attributes of each PAL user. Next, in section VII.2, PAL Activities, we describe how users experienced PALs and how practice was established in different usage scenarios. Finally, in section VII.3, Inferential Findings, we detail how user characteristics and PAL location influence what activities PALs host.

VII.1. Describing PAL User Traits

Our first step in understanding how PALs are used was to identify the traits of its users. Between our interview and observation studies, we took notice of the participant's attributes. First, PAL users in our study were either students (e.g., undergraduate or graduate) or professors (see table 6 and figure 10). Second, PAL users held an affiliation with some academic department such as the Department of Architecture (ARCH). Here,

we will discuss how these two attributes varied among participants across our interview and observation studies.

Descriptive Statistics for Interview Data (Majors)			
Major	n	M	SD
LAUP	5	2.5	0.71
ARCH	7	1.75	0.5
COSC	17	2.125	1.46
VIZA	1	1	N/A
CSCE	4	4	N/A
MISC*	2	1	0
* Majors included are Kinesiology and University Studies			

Table 6. Descriptive Statistics for Interview Data (Majors)
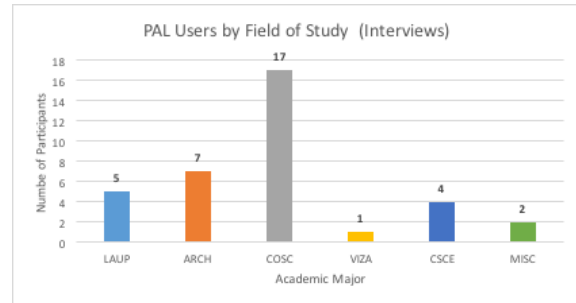
Figure 10. Interviewed PAL Users by Field of Study

VII.1.1. Interview Data

From our interview portion of our study, we collected a total of 17 interviews (see table 7). A total of 2 hours and 50 minutes of interviews were collected, averaging at 10 minutes and 11 seconds. Across the interviews, a total of 36 participants were involved.

Interview Session	Interview Length	Participants Per
1	08:02	1
2	09:42	1
3	08:32	3
4	07:41	2
5	15:41	1
6	12:45	4
7	16:59	2
8	11:30	2
9	08:55	1
10	12:35	2
11	07:27	2
12	11:00	1
13	05:14	3
14	08:24	1
15	06:16	5
16	10:44	3
17	08:44	2

Table 7. Collected Interview Data

We found that COSC was the most frequent users of PALs at a total of 17 participants across the interviews (see figure 10). Following after are ARCH affiliated users with a total of 7 interviews.

Out of the 36 participants we interviewed, 30 of them were undergraduates (Figure see figure 11 and table 8). A total of 6 graduate students were found. No professors were occupying PALs as we conducted the interviews.
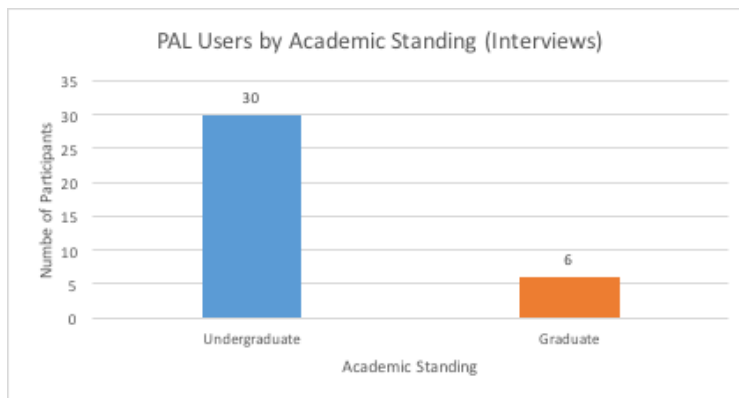
Figure 11. Interviewed PAL Users by Academic Standing

Descriptive Statistics for Interview Data (Academic Standing)			
Standing	n	M	SD
Undergraduate	30	2.14	1.23
Graduate	6	2.00	1

Table 8. Descriptive Statistics for Interview Data (Academic Standing)

VII.1.2. Observation Data

A total of 12 observation sessions were conducted collecting a total of 13 hours

and 27 minutes of data (see table 9). Sessions averaged at 1 hour and 7 minutes per session.

Across sessions, a total of 35 individuals were observed.

Observation Session	Elapsed Time (hours)	Individuals Per Session
Observation_01	0:07	1
Observation_02	0:46	3
Observation_03	0:41	3
Observation_04	0:21	3
Observation_05	1:40	8
Observation_06	1:56	1
Observation_07	2:30	2
Observation_08	1:21	3
Observation_09	0:04	2
Observation_10	0:38	4
Observation_11	1:54	3
Observation_12	1:29	2

Table 9. Observation Data Collected

The three most common users seen during observations included LAUP, ARCH,

and MISC affiliated users (see table 10 and figure 12). A total of 8 LAUP users were

observed across sessions. A single session of ARCH students were observed with a total

of 8 individuals involved.

Descriptive Statistics for Observation Data (Majors)			
Major	n	M	SD
LAUP	8	2	0.82
ARCH	8	8	N/A*
COSC	6	3	0
VIZA	1	1	N/A*
CSCE	4	2	0
MISC	8	2	1.15
*Single instance			

Table 10. Descriptive Statistics for
Observation Data (Majors)
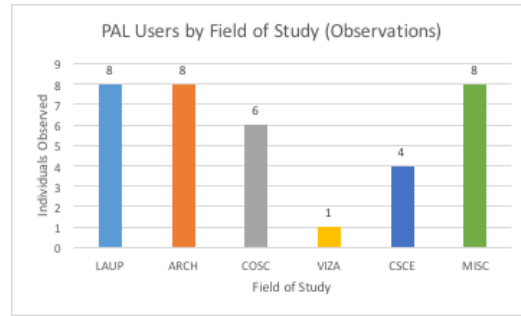
Figure 12. Observed PAL Users by
Field of Study

Undergraduate students were the most frequent users of the PALs during observations with an total of 16 seen across sessions (see table 11 and figure 13). Following closely after are graduate students. Professors saw the least use of the PALs from the sessions.

Descriptive Statistics for Observation Data (Academic Standing)			
Standing	n	M	SD
Undergraduate	16	2.29	0.95
Graduate	14	3.50	1.732051
Professor	5	2	0.57735

Table 11. Descriptive Statistics for
Observation Data (Academic Standing)
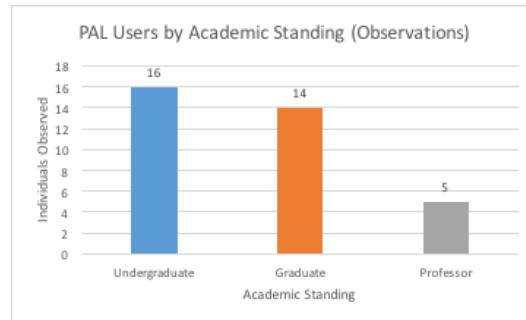
Figure 13. Observed PAL Users by
Academic Standing

VII.2. PAL Activities

To understand how users appropriated PALs in their activities. We focused our analysis on the activity relationship between users and the PALs. Following our analysis, we found that PAL supported activities touch upon the following issues:

- User's Mental Models of Use

- Device Relationships

- Physicality of Work Practice

- Occupant-to-Passerby Interaction.

In this section, we describe categorized themes that emerged from our data analysis. Each categorized theme is organized as follows. First, we describe the overarching concept represented by the theme. Afterwards, we identify the variations of the described theme in the form of codes. Evidence for codes are presented in one of three ways. Direct quotes from interviews are presented as bracketed statements in-between double quotation marks. Notes from observation transcripts are presented as bracketed statements without quotation marks are presented to support the themes identified. Where appropriate, instance frequencies of a theme are reported.

VII.2.1. Device Expectations

Given the fact that PAL users differed in field of study and academic standing, we were interested if these user traits influence how users perceive the purpose of the PALs. From our analysis of the interview data, we identified four themes that describe the various viewpoints users held towards PALs.

'Only for Group Use': The first theme, **'Only for Group Use'**, reflects the idea that because the PALs can support multiple occupants, therefore its purpose is to support group collaborative activities (I-17: *"The only reason I see this is for encouraging more team work and having the space to actually do it."*). Some users extended this idea to concerns of resource management when any PAL was occupied by a single user (I-3: *"You're hogging the space if you're going to just use it for personal work."*).

Contrary to our first theme, some users recognized the benefit of using the PAL's display for single user scenarios. The second theme, **'Larger Screen Real Estate'**, identifies how the PAL's large display enables single users to attend to more on-screen elements. One example case came from a visualization student describing how he used the PAL's display to spread out the windows involved in his activity (I-6: *"When I'm coding, I usually have the display screen on the large display. Because it is easier to see. What I do is having multiple coding files open, so I don't have to jump from one to another."*).

The next theme, **'Detailed View'**, highlights how some users saw no qualification for PAL use between instances of single or group use. Instead, their thoughts on the PAL's purpose revolved around how its resolution supported detailed reviewing of graphical content. One such example of this thought came from a group of COSC students describing their review of a data heavy excel file on building costs (I-8: *" By having a large display, we were able to view the entire layout of a 24 inch by 36 inch page and see the whole schedule."*).

The final theme, **'Content Agnostic'**, refers to how users understood the PALs' display as possessing no design specification for a user or purpose. The final theme,

'Content Agnostic' reflects this idea by highlighting how PAL's displays can be legitimately used across academic to personal work (I-10 "…it does not even have to be for environmental design related work...").

VII.2.2. Describing Use Patterns

In order to understand the design space of the PALs, it was necessary to observe how PAL usage varied across use cases. We approached this issue in two perspectives:

1. What kind of technology was used within the PAL's space?

2. What is the relationship among user's devices and PALs?

From our observations, we saw 27 instances of users engaging personal devices with the PALs. We considered device use regardless if the PAL's display was involved or not. This decision was made in order to compare the display's role to its non-use (e.g., Using laptop screen over large display during use.). The two primary devices that were seen used in the PALs were first laptops (26 devices out of the 48 (54.16%)) and smartphones (19 devices (39.6%)). Not all of these uses were in connection to the PAL's display.

Users made use of two modes enabled by video technology when they had their device connected to the PAL's display. What these two modes offer users in their digital activities is indicative of the role the device and PAL's display have with one another:

- **'Extended Display':** The available working space in a user's personal device is extended beyond the display space of their device.

- **'Mirrored Display':** Content on a user's working space is mirrored in real time on the PAL's display.

5 instances of device-to-PAL relationships were observed. 'Extended Display' was the most frequently seen configuration (4 instances out of the 5.).

VII.2.3. Characterizing Displayed Content

Similar to establishing device use in PALs, we wanted to understand how displayed content could be nuanced. We found two findings regarding displayed content.

First, we identified three roles that displayed content served users during PAL occupancy. Second, there are differences in how users should allocate attention between the PAL's display and other entities (other displays, materials, or other individuals).

VII.2.3.1. Kinds of Displayed Content

Users, engaged in a variety of different on-screen content on the PAL's display. Across observations, the most commonly displayed content included internet browsers such as 'Google Chrome' or 'Firefox' (N=8 (21%)), 'Microsoft PowerPoint' (N=4 (11%), 'Google Sheet' (N=4 (11%)), and CAD (Computer Aided Drafting) (N=4 (11%)). Other applications accessed on the large display are illustrated in figure 14.
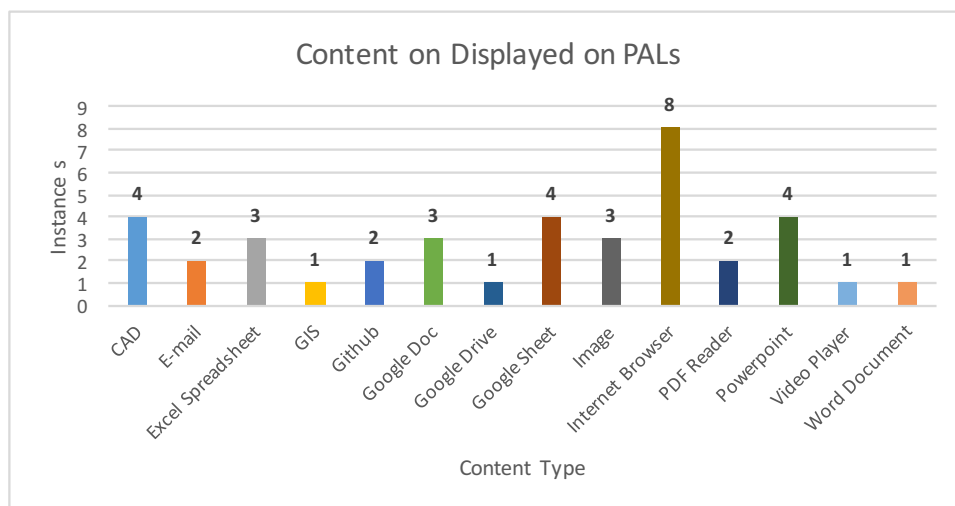

Figure 14. Different Kinds of Displayed Content on PALs

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VII.2.3.2. Purpose of Displayed Content

Users displayed content on the PAL's large display for various reasons. The role of displayed content was dependent upon if the user was engaging in either information consumption or information creation activities. Three high level categories were identified that illustrates the purpose of the content on display:

'Referencing Content' refers to how the large display was used for reference purposes during use. One case involved a user using the PAL's display to keep a ".pdf" of an old exam while having a physical copy of a recent exam on the table. Here the ".pdf" is not the central focus of activity, instead a reference kept on the display when needed. Out of the 14 times that the large display was observed in use, 9 instances were of reference content (27.3%) (see figure 15).

'Reviewing Content' refers to how the large display is used to obtain close- up, zoomed-in, or higher resolutions representations of specific content. One example case saw users cross referencing across different applications (e.g., P13-1 stated: "We blow up our blueprints and our spreadsheets so we can see it in full detail."). Detailed content made up 10 instances of observed large display use (30.3%).

'Editing Content' identifies how the large display served as a point of shared focus as either one user edits, or a group of users suggest edits to be made to the displayed content (E.g., P8-2 mentioned that "*we put some important document on the screen and we discuss it together and try to revise and give advice to each other.*"). This activity was seen to occur at 14 times out of the 33 instances observed for this code theme (42.4%).
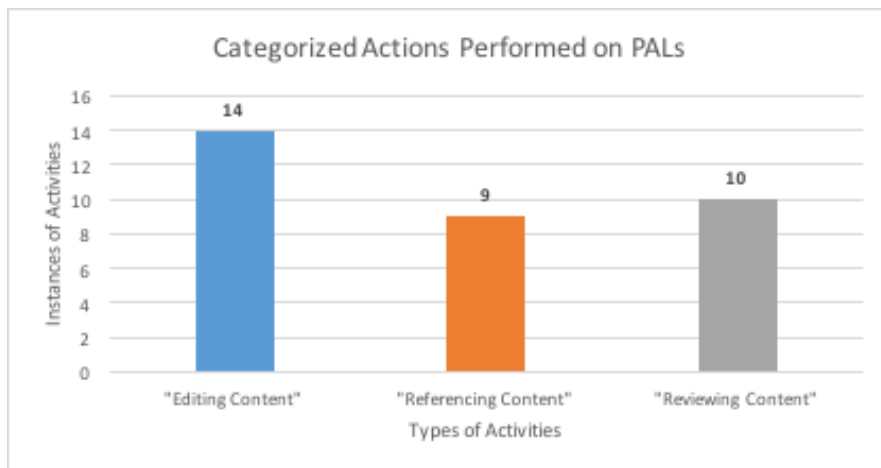
Figure 15. Different Types of On-Screen Activities in PALs

VII.2.3.3. Attention Distribution Among Displays

Gaze fixation was used as an indicator of the type of relationship the users formed between the large display and their laptop's display. The three emergent themed behaviors are described as follows.

The first theme, **'Passive large display use' depicts** gaze fixation occurring towards the laptop display, with glances being periodically taken at the large display. In this case, the large display served as a persistent visual reference. One of observation, for example, involved two users referring to a presentation slide of a motor circuit on the large display. These users intermittently glanced at the display from their laptop, on which they were working on a series of review questions.

'Active large display use' illustrates how users' gazes were fixated primarily on the large display, and glances were taken of the laptop display. An key example of this occurrence was when one user who opened their active work documents (2 internet browsers with different cloud-based documents in each) on the large display, and used the laptop display for personal and background tasks such as checking emails.

'Dead Display Time' represents an active non-use case when the display unit of the supportive PAL was not used by choice. It was often noted that the large display would be connected and used only sporadically, while users focused on work on their individual devices or engaged in oral discussion. The large display would remain on and connected but not in use throughout the duration of supportive PAL use. The display left at idle suggests that the PAL hosts non-display centric activities (e.g., using the PAL for a meeting). Non-use of the display also suggests that active use is episodic in nature rather than a constant.

VII.2.4. Display Usability

Given the mix of users, devices, and kinds of displayed content, we wanted to understand how users could form a mental model towards PAL usage. Here, we found that user's mental models arise from their prior experience with similar technologies, the presence of explicit instructions, or through observing other active user's actions during PAL occupation. How well and easily users could make use of the PALs varied in accordance to three identified influencing factors. The three identified factors are described here within this theme.

'**Familiarity of Technology'** refers to the Personal experience with audio-visual equipment had either a positive or negative effect on users' ease-of-use of the Supportive PAL. In positive cases, users generally knew what needed to be done (e.g., "I mean technology is kind of my generation's thing"). In negative cases, users, ignoring instructions or even the buttons on the HDMI cables themselves, relied on their familiarity with such technology, and attempted to change input channels through the display screen's integrated buttons.

'**Paying attention to the instructions'** highlights whether the user actively read the instructions sign or not coming to the supportive PAL setup made a difference in ease-of-use (e.g., "All the cables up here are all the same so I do not know which one to use. I had to look for the instructions").

'**Observing others'** demonstrates the public nature of the supportive PAL setup enabled users to see other users use the displays, whether consciously observing to know how to use the setup, or unconsciously as one passes by, which helped in later use (e.g., "So I think the more they see other people doing it but that's how they'll learn.").

VII.2.5. Device to Display Connection Issues

A cornerstone feature of the PALs is the capability to connect one's own devices to the displays to enhance their digitally based activities. While this capability saw successful use by users in most cases, we observed different scenarios in which this system saw no use. This non-use of the connection system arose from compatibility issues between users devices and the PAL's display or user's own existing mental models on

shared display usage. This subsection identifies existing issues in the observed installation of the supportive PAL with respect to means of establishing multi-device connections.

VII.2.5.1. Under Utilization of the Switch System

The PAL setup consists of an HDMI switch system that allows users to swap the large display control from one connected device to the other easily. This enables users to share visual information between connected devices without the need to handle the cables themselves. Despite this potential for adoption, this element of the supportive PAL installation, was rarely utilized. Sharing of visual content was still carried out by the users reorienting or repositioning themselves to each other's personal device displays instead, as described above.

VII.2.5.2. Barriers to Establishing Connections

For some cases, it was noted that barriers arose from compatibility issues on the part of its current user's driving device. This was because they lacked the proper port to support this connectivity (e.g., laptops with only a Thunderbolt port or a VGA port). A similar sentiment came about where users expressed an interest in less supported devices to fulfill display such in cases as using a tablet or a smartphone to drive the display content.

VII.2.6. Physicality of Supportive PAL Installation

Group discussion centered on the displayed content was one of the most common activities engaged in the PALs. How individuals refer to displayed content was influenced by where they were located in the PAL's table space. We believe that this variation in user action is indicative of how users' physicality interacts with the PAL's installation. In this subsection, we detail how physicality is reflected in how users interact with displayed

content. In addition, we illustrate how the PAL's table space frames users' physical actions during activities.

VII2.6.1. Bodily Behavior with Supportive PAL

During group occupation of PALs, users frequently gestured towards displayed content. Users engaged in these physical actions to guide attention to specific sub elements of the displayed content. How users were able physically gesture to displayed content was subject to where individuals were located in the PAL's table space. We identified three types of actions towards displayed content.

'Pointing' highlights how users point to specific displayed screen elements to direct attention (e.g., A1 explains something to A3 pointing to the screen element while talking to him). Pointing was the most frequent interaction behavior, occurring 12 times across the 19 instances of observed bodily actions when the large display was in use (63.2%) (see figure 16).

'Touching' provides an extension to 'Pointing' cases where users can further able to direct attention by touching the area of the screen where the specific elements are displayed (e.g., U1 explains a concept to U2, able to not only point, also touch the screen as well). Touching of the display occurred with a single instance.

'Gesturing' refers to how users gesture in the general direction of the display or a subarea of the display to guide attention to on- screen entities generally (e.g., Student A uses his right hand to gesture at the display to guide attention to an element of a concept design while discussing). 'Gesturing' occurred 6 times across the 19 instances (31.6%).
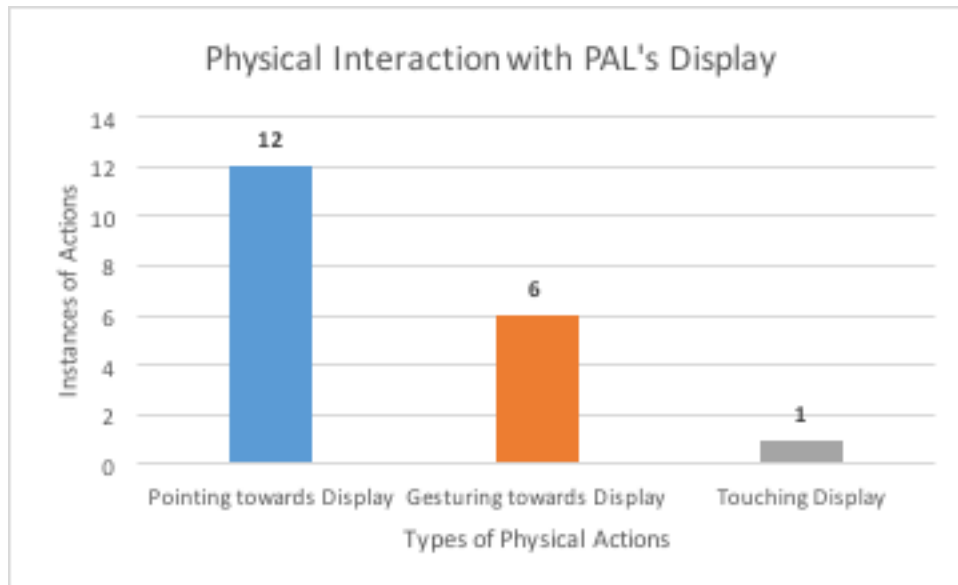
Figure 16. Different Types of Physical Interactions with PAL's Display

PAL Activity Space

The PAL's connected table serves to provide a space where users can engage their activities. The table frames activities through its available area on the table and space surrounding it. Where users are positioned within this space influences their actions and experience of displayed content. Here, we describe three high level codes that illustrate this aspect of usage.

'Table Encourages Group Use' notes that the elongated form of the table attached to the display encouraged groups to gather around the display ("The table is shaped in a way that it is inclusive of all people in your team"). Users have noted that this is made possible by how the space can accommodate multiple users at the same time ("Its convenient that everyone can sit around the display and look at it.") as well as being able

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to face one another ("They are also set up in a way that you face each other and can easily look at the screen, so you can work with each other and see whatever is on the screen.").

'Constrained Viewpoints and Action Possibilities' refers to how the shape and size of the table influenced what is possible within the seated space for users. While the trapezoidal table served to motivate group use, it affected ease-of-use non-equivalently for each user in such group use, and dictated different sets of behaviors. Not all users had an equally comfortable view of the display (e.g., "Users closest to space must maintain fixed rotation of their view to see on screen contents."). How users physically interacted with the displays was dependent on their position at the table relative to the display (e.g., "Users closest to display can either touch or point with accuracy whereas farther displaced users are forced to point from their position or walk up and point to the display.").

'Extraneous Movements' focuses on the movements that arise during thinking and learning processes that could be considered be detrimental to ongoing work. In the case of PALs, we found that the PAL's elongated table required large-scale body movements. The table's form factor often impeded the flow of discussion during episodes of tutoring, collaborative brainstorming, or group editing. To refer to the display content, users had to pause their speech momentarily, walk around the table so to point or touch the display, before resuming their speech.

VII.2.7. Occupant-to-Passerby Interaction

During our observation of PAL users, we took notice of its occupant's interaction with other individuals passing nearby the PAL. Depending on what kind of relationship

the passerby shared with the occupant, this influenced the kind of interaction that could occur. Here, we describe three relationships between PAL occupants and passersby.

VII.2.7.1. Frequencies of Passerby Interactions

Given the size and resolution of the display, passersby of the PAL setup are able to view occupants' activity. We observed this interaction 18 times across our 12 observed use instances (average of 1.5 interactions per Supportive PAL user group). When passersby talked to users, the subject of interactions was primarily focused on academics (10 out of the 18 observed interactions (83.3%)), rather than on socially-oriented topics (1 observed case (8.3%)).

The different types of engagement of the passer-by with the PAL users:

- **'Faculty passer-by and student users':** In cases where the PAL users were students, faculty passer-by engaged into an interaction with the students if i) they knew the students, or ii) the large display was presenting content that they realized related to their activities and tasks (e.g., assignments they gave, their lecture slides, their quiz questions, a subject matter that they know about). The display itself acted as a prompt for interaction, a bridge to conversation, and a means to contextualize discussions with the student users (e.g., "...professors might just pass by and just start talking with students to see where they are at...").

- **'Student passer-by and student users':** The display provided an opportunity for other students to engage in instantaneous peer learning activities, even if they were only impersonally familiar with the users (e.g.,

"Yeah, we have seen a lot of times where we are working here and the our seniors are just walking next to us and they come and they help us because it's in a more open area, we have that kind of interaction").

- **'Stranger passer-by and users':** Irrespective of whether the passer-by was a faculty or a student, if there was no existing relationship between the passer-by and the Supportive PAL users, attention of the passer-by was mostly fixated on how the users are utilizing the space (e.g., "I feel like if I walked over and saw someone using it, I could probably like "oh wow that's a good idea" so like learning from example."). 3 cases of stranger passer-by interactions were observed, as opposed to 4 observed cases of interactions of passers-by with existing relationships to the supportive PAL users.

VII.2.8. Information Sharing Practices

The practice of sharing information snippets is critical in collaborative learning sessions. This practice can be seen in how the large display was used to keep displayed content up. One element of this practice was in the cases where the large display wasn't used. Information was seen shared through user's individual devices. Unlike the large display, information sharing occurred in shorter minute-to-minute time spans rather than the session long use. These activities take the form of working around the PAL's table space. In this subsection, we describe three forms of non-large display based information sharing.

'Casual showings' illustrates how "User A" requires "User B" to obtain common ground on content of a visual nature to be able to proceed with discussion (e.g., student A says "I do not know what this means" and turns his laptop around"; student B leans towards student A's screen as they watch a video together).

'Tutoring' refers to information sharing practices centered on teaching others on how to interact with displayed visual content. An example of this can be where "User A" is guiding "User B" through dense content (e.g., student A moves his chair closer to student B, and guides him through a piece of software code).

'Check-ups' cases come up when '*User A*' wants to see some aspect of '*User B*'s activity (e.g., student A mentions that she accidentally deleted something. Student B leans towards A's device and says that she is "stressing for nothing".).

VII.3. Describing Inferential Findings

In the previous sections, we identified the characteristics of PAL users and how they are used in users' work activities. We also established how the environment can influence PAL activity. Based on these aspects, we were interested in how these attributes can influence what activities the PALs were used for. We hypothesized that differences in how users engaged PALs were subject to the where it was located and its user's own academic interest. Here, we describe the results of tests of significance between floors, individual PAL locations, and academic majors.

VII.3.1. Differences Among Floors

Each floor of the CoA was affiliated with a specific department. The fourth floor was affiliated with the department of Architecture. The department of Landscape and

Urban Planning was in charge of much of the third floor. The second floor differed from the other floors where it housed administrative departments rather than academic departments.

Given the fact that these floors contained classrooms and resources associated with a given department, these floors would be more frequented by those directly affiliated with said department. With respect to the PAL usage, we believed that users' affiliation could lead to differences in passerby-to-occupant interactions.

In order to test for statistically significant differences in PAL occupant-to-passerby interactions, we went over our observation data and performed a count of all instances of non-specified interactions. An Independent-Samples T test was used to compare the averages of instances between floors. There was no statistically significant difference between the third and fourth floor in general passerby interactions (table 12).

Test for Significant Difference in PAL Passerby Interaction Between Floors		
Floor 3 Mean (SD)	Floor 4 Mean (SD)	Independent-Samples T Test
2.33 (2.31)	8.5 (6.36)	t(1.179) = -1.314, p = .388

Table 12. Test for Significant Difference in PAL Passerby Interaction Between Floors

VII.3.2. Differences Between Fields of Study

We previously established that the CoA consists of a wide variety of users. One source of this variance was the fields of study that each PAL user was associated with. Based on this user trait, we were interested if one's field of study would influence how they would use the PALs in their own practice. Here, we will describe the results of the inferential tests we ran concerning these issues.

VII.3.2.1. Results for Significant Differences for Passerby Interactions

Given the fact that each floor housed specific departments and classrooms, we believed that this would have a effect on the kinds of passerby to occupant interactions that would occur. We conducted a one-way ANOVA considering the instances of the following forms of passerby-to-occupant interactions:

Instances of Passerby Interaction (General Interactions)'

Instances of Passerby Interaction (Occupant-to-Student Peers)

Of these tests, we found that there were no statistically significant differences between user's field of study (see table 13).

Test for Significant Difference in PAL Passerby Interaction Between Majors				
	LAUP Mean (SD)	ARCH Mean (SD)	MISC Mean (SD)	One-Way ANOVA
General Interactions	2.33 (2.31)	13 ()	4 ()	F(2,2) = 8.075, p = .110
Passerby Interaction (Student)	3(2.82)	4 ()	3()	F(2,1) = .047, p = .956

Table 13. Tests for Significant Difference in PAL Passerby Interaction Between Majors

Representative student of the observed academic majors utilized a variety of digital devices in the form of laptops, tablets and smartphones. Frequency of use of these various devices saw no significant difference between academic majors (see tables 14-16).

Test for Significant Difference Among Majors on Device Usage (Simultaneous Device Usage)					
LAUP Mean (SD)	ARCH (SD)	COSC (SD)	CSCE (SD)	MISC (SD)	One-Way ANOVA
4.25 (0.96)	4 ()	2.5 (0.71)	4 ()	2.5 (1.73)	F(4,7) = 1.202, p = .389

Table 14. Test for Significant Difference Among Majors on Device Usage (Simultaneous Device Usage)

Test for Significant Difference Among Majors on Device Usage (Smartphone Usage)			
LAUP Mean (SD)	CSCE (SD)	MISC (SD)	One-Way ANOVA
1.75 (0.5)	2 ()	1.5 (0.71)	$F(2,4) = .286$, p = .766

Table 15. Test for Significant Difference Among Majors on Device Usage (Smartphone Usage)

Test for Significant Difference Among Majors on Device Usage (Laptop Usage)				
ARCH Mean (SD)	COSC (SD)	CSCE (SD)	MISC (SD)	One-Way ANOVA
3.6 (1.95)	3.5 (3.54)	1 (0.00)	6 ()	$F(4,7) = .942$, p = .493

Table 16. Test for Significant Difference Among Majors on Device Usage (Laptop Usage)

General information sharing activities saw statistically significant differences between majors ($F(2,7) = 7.827$, p = 0.016) (Table 17). A Tukey post hoc test revealed that COSC affiliated users engaged in more information sharing activities than MISC students (4 ± 1.09, p = 0.019). There were no significant differences between COSC and LAUP students (p=4.0). In addition, there was no statistically significant differences between LAUP and MISC students (p=0.59). We ran tests also on specified forms of information sharing, but found no statistically significant differences among fields of study.

Tests for Significant Differences Between Fields of Studies on Information Sharing				
	LAUP Mean (SD)	COSC Mean (SD)	MISC Mean (SD)	One-Way ANOVA
Information Sharing (General)	5.56 (2.00)	5.00 (5.00)	3.25 (0.00)	$F(2,7) = 7.827$, p = 0.016
Casual	2.77 (0.00)	7.85 (1.00)	1.42(0.00)	$F(2,7) = 1.441$, p = .299
Tutoring	2.27 (0.00)	2.00 (2.00)	1.05 (0.00)	$F(2,7) = 4.100$, p = .066
Check Up	1.5 (1.29)	1.5 (0.71)	0.25 (0.5)	$F(2,7) = 2.100$, p = .193

Table 17. Tests for Significant Difference Between Fields of Studies on Information Sharing

VII.4. Conclusions

In this chapter, we articulated our findings on how PALs support users in their digitally based activities. We first identfied the traits that each PAL user posessed, these being field of study and academic standing. Afterwards, we identified the how these users interacted with PALs, spanning issues such as users' mental models, technology used, and practices established. Finally, we compared the frequency of emergent activity outcomes between users' field of study and PAL location. We found that field of study had an statisically significant effect on digital information sharing practices. With respect to location, there was no statiscally significant effect on place in emergent passerby-to-occupant interactions.

CHAPTER VIII

DISCUSSION

This study sought to understand how PALs support users in their digitally based activities. We tackled this issue across three research questions:

- **RQ 1:** *How well do users take advantage of and appropriate designed features of PALs?*

- **RQ 2:** *In what ways do users exhibit non-use of the PAL's features?*

- **RQ 3:** H*ow do the PALs exist in terms of notions such as a space and place?*

    In pursuing these questions, we put forth the following hypothesis:

- *Experiential differences in PAL use can be attributed to both the users' scope of activity and attributes of the surrounding environment.*

    In this chapter, we use the concepts covered in Chapter III and generalize the findings from Chapter VII to answer our set research questions.

VIII.1. RQ 1

Users' appropriation of PALs is made possible through two elements of work practice. First, appropriation by the ways users understand how to operate the PAL. Second, how users negotiate the specifics of their activity with the PAL's generic design.

VIII.1.1. Ways of Understanding PALs Operation

Users appropriated PALs by forming their own understanding from one of three ways. First, users reported that they saw similarities between the PAL's display and the kind they may encounter in their home. Second, if users lacked familiarity with AV technologies, they relied upon the attached information card. Third, users looked to their peers to understand how to use the PALs. This was noted from PAL users' interviews. In

addition, we believe that how passersby's' gaze fixates on the PAL's display as they walk by may be indicative of how users may indirectly learn from other's use of the PAL.

These various ways of understanding can be placed within the earlier stages of Carol et al.'s "Technology Appropriation Model"(Carroll et al., 2001). Specifically, the instructional card placed on each PAL's table supports users in the "technology-as-designed" stage, where it offers its purpose and worth towards users' activities and how to operate it. "Technology-as-designed" plays an indirect role in the other two means of understanding, where its overall physical setup offers clues to prospective users as to what it can potentially offer them. Instead, "passersby's gaze" and "similarities to existing technologies" are closer to the stage of the TAM's "process of appropriation", where users gain knowledge of the PALs and begin to form an attitude towards it. Specifically, users remarks on the PAL's similarities to other technologies is indicative of attitude formation.

VIII.1.2. Negotiating Specific Activity with Generic PAL Design

When it came to the specifics of the kind of PAL activity engaged, it was the users, not the designers, that defined the activity. This is in line with Dourish's observation, where he notes that while designers develop the form and function of an interactive artifact, ultimately it is the user who determines its coupling with their activity (Dourish, 2004). The exact use of an artifact arises from the users specific and situated activity.

This aspect of appropriation was seen in the variety of activities that users engaged in. For example, information sharing practices were significantly different between academic groups. Each group had its own needs in using the display. ARCH affiliated students, given the visual nature of their architectural designs, saw the highest frequency

of information sharing during use. CSCE students were the second frequent group, as seen as the display was changed between users when identifying an issue common to the group. COSC was the third group, where information sharing was based on textual information for reference purposes rather than visual review. Here, the various ways that the displays are being used among groups is indicative of users in the "technology-in-use" stage. Here, users decided for themselves the utility of the PAL's display and established specific practices for their personal or group needs. Our data so far can only suggest the end effects of this process and not the evolution of these practices as time progresses.

VIII.2. RQ 2

In designing technological devices, it is important to consider why users choose to disengage devices in context. In our study, we found that users exhibited non-use of the PAL in two ways. The first form of non-use was seen in users' attention redistribution between the PAL's display, mobile devices, and other individuals. Users also exhibited a second form of non-use with respect to the PAL's switch system. We generalize these findings as follows.

VIII.2.1. Attention Distribution Between Displays

Users did not always make active use of the PAL's display in their activity. We observed differences in the frequency and period of user fixed gaze between the PAL's display, mobile devices, and other occupants of the space. The PAL's display saw transitions of active use and passive use as users engage their activity. We suggest that this shift between use and non-use indicates the PAL's role in users' activities. The PAL's display is not only for the representation of digital content, but also for persisting future

work. This can be seen in cases where the PAL's display was used in the "extended configuration", where content is placed and referred to on occasion as attention is redirected toward the PAL's display.

This can be seen when users shift their attention from other devices or users to glance content on the PAL's display. After glancing content, users would return their attention elsewhere. In characterizing the role that the PAL's display serves in such scenarios, we can think of it as digital analog to a workbench. Like a workbench, the display serves as the site of activity but also a place where activity can be referred to when not in immediate use.

Sambasivan (Sambasivan et al., 2009) identifies one form of "avoidance by the user" through the "deliberate shutting down of portables" in an effort to better engage the surrounding physical world. Non-use was similar to this theme where the displays while not powered down, were not the object of attention at various points of occupation. In addition, attention was focused not only on elements of the physical world such as other users or physical artifacts (e.g., notes and books) but also other digital displays (e.g., laptop's own connected display or smartphones).

One example of non-use of the display was the frequency active use among groups. Non-use of the display saw the highest frequency with CSCE majors versus CoA affiliated majors. We believe that this is because of the kind of activities that CSCE majors engage in versus CoA majors. CoA majors relied on the PAL for discussion, so the display component was always in use. For CSCE majors, the display went out of their attention, in that each user would refer back to their individual device. The display was used in this

case as persistent information reference, used when needed. Here, the non-use of the display in this fashion is similar to how the "Kupla" displays in Jurmu et al.'s work (Jurmu et al., 2014) was used with respect to supporting common reference needs and persistent notification needs. The use demonstrated here differs from the Jurmu et al' s work, where display usage in this fashion occurred in a day-by-day timeline whereas use in the PALs was in a minute-by-minute timeline.

VIII.2.2. Underutilization of the Switching System

Existing data from the study does not offer direct explanation as to why the connection system was underutilized within observations. What can only be speculated is the reason when in scenarios where they could have been used.

One such scenario was seen when users share their digital content on their devices. Users shared content by either reorienting/repositioning their devices towards other's view. Another approach was for users to physically reposition themselves towards others' display.

In addressing such a scenario, it is possible that users perceive greater immediacy in sharing through the above-mentioned style versus using the switch system. Another reason we offer is that the content shared was relevant within a short time span. Should information find utility beyond this time span, content could warrant extended use and trigger a switch. This potential form of non-use of the switch system is can fall in line with Sambasivan et al's theme, "resistance by the user", where technology is considered intrusive by either being unnecessary, unwelcomed, or forced upon the user. For this form

of non-use, the PAL's switch system was deemed unnecessary with respect to information sharing where there are more direct means of accomplishing the activity.

VIII.3. RQ 3

The spaces of which the LDTs were installed had an effect of influencing the potentiality of certain activities to occur within its given space. How spaces are utilized and how they become places with respect to LDTs are covered below.

VIII.3.1. Finding: Physicality of User Behavior within PAL Activity Space

The physicality of user activity was evident in three aspects in PAL use. First, users engaged in various bodily activities (e.g., gesture, point, touch) when using PALs in group use scenarios. This bodily activity served the purpose of linking discussion with displayed content. It can be speculated that user's physical interaction was subject to the level of specificity warranted by discussion. Gesturing was observed to occur when the topic referents were broad. Pointing or touching, appeared in cases where users wanted to direct attention to specify specific components of displayed content.

Second, the PAL's attached table space had the effect of influencing user's activities and experience when occupied. Harrison and Dourish's notion of "space" (Harrison & Dourish, 1996) was noticed in the way users interacted with content within the PAL's table space. This was seen as one participant mentioned, the shape of the table encouraged users to be closer to one another. This could support collaboration by reducing social barriers between users. The table itself also had an effect of limiting the action possibilities due to their location. For user's closest to the display, they can easily point or touch the display, but their view of the display could be difficult to maintain due to how

close they are. Those farthest away can easily view the displayed content, however with respect to bodily engagement, users would need to physically move themselves to affirm which element they were referring to. "Proximity and Action" was demonstrated here when users performed some kind of physical action with respect to on screen action (Harrison & Dourish, 1996). If users were further away from the screen and needed to point to a specific displayed element, they would need to move closer towards it in order to accomplish this action. Similar to this, "partitioning" is reflected here where actions are limited to users relative location within the PAL's table space. This aspect of differential interaction with the display can prove to be beneficial or detrimental to users. For example, while users closest to the display can touch the screen they may have discomfort in viewing it in close view. This concern is similar to what Su and Bailey (R. E. Su & Bailey, 2005) reported in view as the viewing angle of the screen will exceed 45 degrees for the user in that specific area of the table space.

Third, the PAL's table space should not only accommodate users but their personal artifacts also. One issue that was noted by a group of users was the disconnect between the number of users and the quantity of power plugs. The relationship between the connection ports and the physical space of the table needs to be considered in order to ensure that not just users, but their device collections can be accommodated for.

VIII.3.2. *Serendipitous Passerby Activities due to Spatial Location in Place*

Harrison and Dourish's notion of "Place" (Harrison & Dourish, 1996) was seen in how individuals passing near the PALs display interacted with a given PAL and its current occupants. Specifically, we saw this in how the interaction between physical location and relationship to users could lead to direct engagement with the PAL's display.

We found instances of passersby varying in their interactions with "PAL-3" and "PAL-8" respective to floors 3 and 4. Similar to Dix and Sas' (Dix & Sas, 2008) categorization of surrounding individuals of a LDT, we identified three possible relationships held between passersby and current PAL occupants:

- **'Stranger-Occupant':** When there was no social relationship between a passerby and the occupant, the passerby's interaction was that of an observer. When this interaction occurred, participants either maintained a fixated glance towards the LDT as they were walking. It is possible from this interaction that users are learning from users activities, due to the scale of the display as well as the visibility of their actions.

- **'Occupant-Student':** When the relationship is 'occupant to student', the occupant knew the passerby. This was seen through how passersby moved closer to the occupant and began to converse on topics pertaining to class. What can be said about this exchange is that it creates a space where classroom activities are supported and extended. These actions can result in short exchange such as checking up or them joining with the occupants.

- **'Occupant-Professor':** When the relationship is occupant to professor, it presented an opportunity for impromptu instruction beyond the classroom. If the professor was aware of the student and saw their activities were relevant to their own academic interests, the professor may feel comfortable to interact with the occupants. This could manifest in speaking briefly with students to review or critique their work as they are passing by, given that the faculty offices are located nearby the PALs.

If passersby held some kind of peer or mentor based relationship to PAL occupants, this served to encourage them to transition from a passerby to bystander and possibly an active user as they pass through the PAL's levels of "activity spaces" (Brignull & Rogers, 2003). Passersby transitioning between a passive actor to a PAL to an active user could be attribute to one of two sources. Brignull and Rogers' *"Honeypot Effect"* could be seen here where the presence of individuals who appear open to socializing may serve to motivate engagement. The CoA's culture of collaboration in seen in its disciplines may also be another attribute, as suggested by Churchill et al.'s observation on *"Organizational Culture"* (Churchill et al., 2004) and social focused end use of LDTs.

Altogether, this created opportunities for both PAL occupants and passerby to extend relationships beyond the classroom context. This reflects one of the Harrison and Dourish's place-based themes, specifically *"Place in the Built Environment"*. This is seen as the interaction between the location of the PAL and frequent passersby resulting in the PAL acting as an extension of the classroom for users associated with a given floor.

VIII.4. Design Guidelines

In closing this section, we describe a set of design guidelines for the design or deployment of PALs. Each set is organized to the how PALs support users in appropriation, non-use, spatial and place based work.

VIII.4.1. Appropriation

In supporting how users appropriate PALs, we suggest the following:

- **'Ways of Learning':** When communicating the design model of a PAL, stakeholders should be aware of the ways users establish their own mental model of usage. Users establish their own understanding of a PAL's design model in one of three ways. First, users will rely upon their prior experience with technologies similar to PALs and adapt that knowledge in guiding use. Second, if users lack familiarity with PALs related technologies, signs should be highly visible and informative at a novice level. Third, users can observe how their peers are using the PALs and indirectly learn how to operate and the social mores associated with its use.

- **'Generic Design':** PALs should be designed with a minimal assumption on the tools, and protocols necessary for its expected users' activity. In order for a PAL to afford wide appropriability, it should support the foundational elements of user activity. There are two ways wide appropriability can be supported. First, technology support should be representative of the kinds of technology used or in access by its user population (e.g., having display-to-device connection protocols for

students' laptop devices). Second, the PAL's design shouldn't focus on the details of activity but the type of activity (e.g., shift focus from supporting building review, to supporting discussion and presentation). Supporting these two elements will provide the foundation for users to take over and craft their PAL experience based on their specific needs.

VIII.4.2. Non-Use

- **'Display acts as a Digital Workbench':** The display of a PAL shifts between periods of use and non-use in relation to its current users activity. The PAL's display role in a users activity can be likened to a workbench. At times, the LDT is used to better represent visual content or to handle multiples of content. In other times, the LDT goes out of active use in an users' workflow. While the users' attention is elsewhere, its contents persist. Should users reengage the LDT, they can easily re-access their content as before, in the same position and state.

VIII.4.3. Space and Place

- **'Accommodate for Physical Practice':** Users' physical work practices should be reflected in the PAL's installation. PAL supported user activity is not restricted to the digital display, instead its spread out into the PALs physical space. Users rely on the PAL's physical space in two ways. First, they use the PAL's immediate space to store or interact with their personal artifacts (e.g., using the attached table to write on or keep notes in reference). Second, users establish common ground between one another

by pointing or gesturing towards displayed content (e.g., one student points to a specific section of a plan during discussion).

- **'Place Relationship':** Where a PAL is situated in a place can influence the kind of occupant-passerby interaction to emerge. Places tend to have individuals that are associated with it. This can determine who uses the PAL of a given location and passersby. There are two possible interactions between occupants and passersby. First, if passersby are strangers to occupants, passersby can potentially learn from the occupants use of the PAL (e.g., a passerby fixes gaze towards PAL while walking). Second, should passersby hold some relationship with occupants, the PAL's displayed content can give passersby a contextual handle to interact with occupants.

CHAPTER IX

CONCLUSION

Our study inquiry came from noticing a trend that LDTs are becoming commonplace in various public settings. In addition, we noted that these displays were freely appropriable for users' digitally based activities. We believe that this rise in LDT installation is indicative of our need to engage in mobile information work. In our study, we identified this specific type of LDT as PALs. Potentially, users can use these PALs to easily engage in their activities just as they would at home or in the office.

For our study, we wanted to examine how PALs currently support user's digital activities and where future development can improve user outcomes. In our conclusion, we will first consider the wider significance of our study findings. Afterwards, we will identify the weaknesses that exist in the present study. Finally, we will point out directions for future work.

IX.1. Significance of Study

Our work contributes to the LDT literature by illustrating the dynamic relationships that exist among PALs, users, devices, and the surrounding environmental context. We identified these dynamics by breaking down out study objectives in three trajectories.

First, we sought to understand the various ways users' activities were supported in appropriation. Second, we saw not only how users engaged PALs but in what ways the installation transitioned in and out of active use during activity. Third, we found that PALs had space and place-based attributes during user occupation.

For stakeholders, we described a set of design guidelines specific to university-based information workers' workflow. Our guidelines can be generalized to other settings given the similarities of users' activities to one another.

IX.2. Weaknesses and Future Directions

While we could understand how PALs supported users' digital activities, our findings are limited by the dynamics unique to our setting and our approach. Here, we identify the specific weaknesses of our study and address how future work could extend our findings.

IX.2.1. – Generalizability of Study Population

While our study population varied in their academic interests, the overall population was still centered around the discipline of Architecture. It would be novel to examine in what ways other student populations (e.g., engineering or liberal arts) would utilize the PALs. Specifically, in what ways are other student groups analogous to architecture-affiliated students? In addition, what kind of support would non-architecture students need in engaging their digitally based activities? Beyond students, future work should also consider the workflows of professionals for these same reasons.

IX.2.2. Consideration to Place-based Temporal Dynamics

We noted that some of the CoA's PALs were time restricted, specifically the LAUP affiliated units. Our study currently does not fully address the relationship between PAL usage with respect to temporal context. Future work in this inquiry is worthwhile given that there are certain passerby-occupant relationships that are determined by the time of day. Work in this area could illustrate further how PALs supports the social aspects

of user's activities. Examples of such scenarios could be between class periods or after hours use.

IX.2.3. Activity Outcomes between Places

Our study was framed within a specific university setting, limited in its use by the interaction of physical setting, context, individuals, and activities pursued. Future work should observe how PALs are integrated in various settings, such as libraries or civic centers. While previous studies have observed LDTs set in such settings, those works represented cases of activity limited LDTs, rather than PALs. It would be novel to observe what kind of practices and supports are necessary to successfully integrate PALs in these settings.

REFERENCES

Brignull, H., & Rogers, Y. (2003). *Enticing people to interact with large public displays in public spaces.* Paper presented at the Proceedings of INTERACT, 3, 17-24

Brown, M., & Long, P. (2006). Trends in learning space design. *Learning spaces*, 9.1-9.11.

Carroll, J., Howard, S., Vetere, F., Peck, J., & Murphy, J. (2001). Identity, power and fragmentation in cyberspace: technology appropriation by young people. *ACIS 2001 Proceedings*, 6.

Churchill, E. F., Nelson, L., Denoue, L., Helfman, J., & Murphy, P. (2004). *Sharing multimedia content with interactive public displays: a case study.* Paper presented at the Proceedings of the 5th conference on Designing interactive systems: processes, practices, methods, and techniques, 7-16

Ciolfi, L., & De Carvalho, A. F. P. (2014). *Work practices, nomadicity and the mediational role of technology.* Paper presented at the Computer Supported Cooperative Work (CSCW), 23, 119-136

Construction Science Program at Texas A&M University. Retrieved from http://cosc.arch.tamu.edu/about/

Czerwinski, M., Smith, G., Regan, T., Meyers, B., Robertson, G. G., & Starkweather, G. (2003). *Toward characterizing the productivity benefits of very large displays.* Paper presented at the Interact, 3, 9-16

Dix, A. (2007). *Designing for appropriation.* Paper presented at the Proceedings of the 21st British HCI Group Annual Conference on People and Computers: HCI... but not as we know it-Volume 2, 27-30

Dix, A., & Sas, C. (2008). *Public displays and private devices: A design space analysis.* Paper presented at the Proceedings of the SIGCHI conference on Human factors in computing systems (CHI 2008),

Dourish, P. (2004). *Where the action is: the foundations of embodied interaction*: MIT press

GmbH, M.-D. b. V. MAX QDA: Qualitative Data Analysis. Retrieved from http://www.maxqda.com/

Harrison, S., & Dourish, P. (1996). *Re-place-ing space: the roles of place and space in collaborative systems.* Paper presented at the Proceedings of the 1996 ACM conference on Computer supported cooperative work, 67-76

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research, 15*(9), 1277-1288.

Huang, E. M., Koster, A., & Borchers, J. (2008). *Overcoming assumptions and uncovering practices: When does the public really look at public displays?* Paper presented at the International Conference on Pervasive Computing, 228-243

Inquirium, L. InqScribe: Digital Media Transcription Software. Retrieved from https://www.inqscribe.com/

Jurmu, M., Goncalves, J., Riekki, J., & Ojala, T. (2014). *Exploring use and appropriation of a non-moderated community display.* Paper presented at the Proceedings of the 13th International Conference on Mobile and Ubiquitous Multimedia, 107-115

Kuikkaniemi, K., Jacucci, G., Turpeinen, M., Hoggan, E., & Müller, J. (2011). From space to stage: How interactive screens will change urban life. *Computer, 44*(6), 40-47.

Kuikkaniemi, K., Lehtinen, V., Nelimarkka, M., Vilkki, M., Ojala, J., & Jacucci, G. (2014). *Designing for presenters at public walk-up-and-use displays.* Paper presented at the Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction, 225-232

Landscape Architecture and Urban Planning Programs at Texas A&M.   Retrieved from http://laup.arch.tamu.edu/academics/graduate/

Luff, P., & Heath, C. (1998). *Mobility in collaboration.* Paper presented at the Proceedings of the 1998 ACM conference on Computer supported cooperative work, 305-314

Müller, J., Alt, F., Michelis, D., & Schmidt, A. (2010). *Requirements and design space for interactive public displays.* Paper presented at the Proceedings of the 18th ACM international conference on Multimedia, 1285-1294

Ojala, T., Kukka, H., Lindén, T., Heikkinen, T., Jurmu, M., Hosio, S., & Kruger, F. (2010). *UBI-hotspot 1.0: Large-scale long-term deployment of interactive public displays in a city center.* Paper presented at the Internet and Web Applications and Services (ICIW), 2010 Fifth International Conference on, 285-294

Oudshoorn, N., & Pinch, T. (2003). *How users matter: the co-construction of users and technology (inside technology)*: the MIT Press

Peltonen, P., Kurvinen, E., Salovaara, A., Jacucci, G., Ilmonen, T., Evans, J., . . . Saarikko, P. (2008). *It's Mine, Don't Touch!: interactions at a large multi-touch display in a city centre.* Paper presented at the Proceedings of the SIGCHI conference on human factors in computing systems, 1285-1294

Plaue, C., & Stasko, J. (2009). *Presence & placement: exploring the benefits of multiple shared displays on an intellective sensemaking task.* Paper presented at the Proceedings of the ACM 2009 international conference on Supporting group work, 179-188

Rice, R. E., & Katz, J. E. (2003). Comparing internet and mobile phone usage: digital divides of usage, adoption, and dropouts. *Telecommunications Policy, 27*(8), 597-623.

Robertson, G., Czerwinski, M., Baudisch, P., Meyers, B., Robbins, D., Smith, G., & Tan, D. (2005). The large-display user experience. *IEEE computer graphics and applications, 25*(4), 44-51.

Rogers, Y., & Lindley, S. (2004). Collaborating around vertical and horizontal large interactive displays: which way is best? *Interacting with Computers, 16*(6), 1133-1152.

Sambasivan, N., Ventä, L., Mäntyjärvi, J., Isomursu, M., & Häkkilä, J. (2009). *Rhythms of non-use of device ensembles.* Paper presented at the CHI'09 Extended Abstracts on Human Factors in Computing Systems, 4531-4536

Scheible, J., Ojala, T., & Coulton, P. (2008). *MobiToss: a novel gesture based interface for creating and sharing mobile multimedia art on large public displays.* Paper presented at the Proceedings of the 16th ACM international conference on Multimedia, 957-960

Su, N. M., & Mark, G. (2008). *Designing for nomadic work.* Paper presented at the Proceedings of the 7th ACM conference on Designing interactive systems, 305-314

Su, R. E., & Bailey, B. P. (2005). *Put them where? towards guidelines for positioning large displays in interactive workspaces.* Paper presented at the IFIP Conference on Human-Computer Interaction, 337-349

Sullivan, T. J. (2001). *Methods of social research*: Harcourt College Publishers

Ten Koppel, M., Bailly, G., Müller, J., & Walter, R. (2012). *Chained displays: configurations of public displays can be used to influence actor-, audience-, and passer-by behavior.* Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 317-326

Undergraduate The Bachelor of Environmental Design Program. Retrieved from http://dept.arch.tamu.edu/undergraduate/

Visualization Program at Texas A&M University. Retrieved from http://viz.arch.tamu.edu/about/

Vogel, D., & Balakrishnan, R. (2004). *Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users.* Paper presented at the Proceedings of the 17th annual ACM symposium on User interface software and technology, 137-146

Wallace, J. R., & Scott, S. D. (2008). *Contextual design considerations for co-located, collaborative tables.* Paper presented at the Horizontal Interactive Human Computer Systems, 2008. TABLETOP 2008. 3rd IEEE International Workshop on, 57-64