The introduction of a shared interactive surface into a communal space

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ABSTRACT
We describe a user study of a large multi-user interactive surface deployed for an initial period within a real world setting. The surface was designed to enable the sharing and exchange of a wide variety of digital media. The setting for the study was the common room of a high school where students come together to mix, socialize, and collaborate throughout the day. We report on how the students use the new technology within their own established communal space. Findings show that the system was used extensively by the students in a variety of ways, including sharing of photos, video clips, and websites, and for facilitating social interaction. We discuss how the interactive shared surface was appropriated by the students and introduced into their everyday lives in ways that both mirrored and extended their existing practices within the communal space.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces - evaluation/methodology, prototyping, user-centred design; H.5.3 [Information interfaces and presentation]: Group and organization interfaces - asynchronous interaction, synchronous interaction.

General Terms
Design, Human Factors.

Keywords
Situated display, multi-user interfaces, communal space, adoption, user study

1. INTRODUCTION
The use of large interactive displays has an established history in supporting collaborative and group-based activities [e.g., 18, 24]. Primarily, they have been used to support various cooperative activities that occur within meeting rooms, classrooms, offices and other workplaces [e.g., 3, 16, 18, 24]. More recently, researchers have begun to situate large displays within communal and more informal settings [e.g., 2, 7, 10, 17, 22]. These settings are quite different from work-based environments, both in terms of their social and technological composition and offer new opportunities for interactive large displays. Rather than being a single-purpose tool, large displays can be used as shared resources for a variety of community-based activities, such as catching up and coordinating with others, sharing information, and socialising.

We are concerned with how novel technologies, in particular large interactive displays, can be introduced into established communal spaces. Our goal is to understand how such technologies can be successfully adopted within a given communal space in terms of how they support and extend existing activities and practices (such as, socialising and sharing). To begin to explore these issues, we have conducted a study of a large interactive display system, Dynamo [13], within a common room used by a community of high school students. We have designed and developed Dynamo to provide a *public interactive surface* for sharing, exchanging, showing and interacting with a wide range of digital media.

In the paper we first outline the key features of the Dynamo system and then describe its deployment within the high school common room. We describe the communal nature of the space before Dynamo was situated within it and report on the ways in which the students used this new technology. We discuss how the system was introduced into the existing ecological arrangement of the physical space, and examine the initial adoption and social effects that arose. Finally, we conclude by reflecting on the implications of designing shared interactive displays for supporting social activities in communal settings.

2. RELATED WORK
Early research on shared interactive surfaces focused on designing novel interaction techniques for collaborative work. For example, the electronic whiteboard system, Tivoli [18], consisted of an interactive display designed to support freehand pen input, enabling users to draw on a large screen and share their drawings with others at a meeting. Since then, there has much interest in developing freehand and gesture-based interaction, to enable more fluid styles of interaction with the surface [e.g., 12, 19].

Another approach has been to embed displays as part of the physical environment to support various forms of collaborative activities. Examples include iRoom [14] and iLand [25], which offer a variety of interconnected displays to support meetings. Other work on interactive surfaces includes the use of augmented tabletop displays [4, 19, 23] and multiple displays for supporting small groups of users [9, 20].

Many large display systems are currently single-user based and require users to take turns when interacting with them. There is a growing body of work, however, that is investigating the use of

multi-user interactive displays [e.g., 3, 6, 16, 23]. Recent examples include the Pebbles system [16] which allows PDAs to be connected to a single large display to provide concurrent input, Kidpad [3] which supports multi-mice input to promote learning within the classroom, and [23] which supports collaboration through a multi-user tabletop touch display.

Another focus of large display research has been on augmenting noticeboards found in communal areas, halls and foyers of organizations. For example, Plasma Poster [7, 8] and Community Wall [10] were designed to enable people to post and annotate information onto a large public display available to a community of users. Systems such as the Notification Collage [11] and Kimura [27] offer an overview of the activities of a community of users as a form of shared awareness. Another kind of surface intended for community use are 'walk up and use' interactive boards. An example is Blueboard [22], which allows identified users at the board to quickly display personal information (such as personal calendar and messages) held on the network and share this with others via mediums such as email.

A key objective of this line of research has been to consider how placing displays in public settings improves a 'sense of community', through fostering social encounters and an enhanced awareness within the community [e.g., 5, 7, 10, 15]. However, researchers have often found that it can be difficult (particularly initially) to get members of the community to voluntarily and spontaneously use such displays in these kinds of settings. For example, Churchill et al [8] found that people needed constant encouragement and demonstration to interact with the public display and Agamanolis [1] notes how "half the battle in designing an interactive situated or public display is designing how the display will *invite* that interaction" (p.329). One of the reasons for this initial reluctance to use novel public display systems may be that it is not clear to the members of that community how they can integrate them with their existing practices. Another reason may be that people can be self conscious and inhibited when required to do new things and act out in a public arena. These experiences around the design and use of large screen displays frame the background for our own investigations.

3. THE DYNAMO SYSTEM

Drawing from a number of preliminary studies of communal surfaces in use and early prototypes [5, 21], the Dynamo system was developed to support multi-user interaction with digital media on a large surface and make the exchange and sharing of media a lightweight and easy to accomplish activity. Multi-user interaction is supported through *interaction points* (typically wireless keyboards and mice or laptops) that may be placed freely around the space. This approach reduces the impact of bodies standing in front of the surface occluding the on-screen content from others.

The Dynamo system allows digital information to be exchanged via an assortment of devices and interactive surfaces, such as removable USB pen drives, laptops and digital cameras. For this particular deployment, we allowed people to plug in their physical devices to USB hubs connected to the Dynamo system and access their digital information upon the display. Users could drag their digital media (e.g. video clips, text files, digital images, PowerPoint slides, audio files and documents) onto the Dynamo surface, where it could be displayed, interacted with, organised, copied and left for others.

An example of the Dynamo surface is shown in Figure 1. Each interaction point is represented by a colour-coded telepointer. Information is moved onto and off of the surface using *palettes*. A palette consists of a number of distinct items, represented by icons, which can act as 'sources' and 'sinks' of media. A media source can be dragged off the palette and displayed on the Dynamo surface. For example, a source wrapping a video file can be dragged onto an accessible region of the surface whereupon the file is opened, rendered on screen, and can be interacted with. Similarly, the user can drop media onto a media sink item within the palette for processing. For example, dropping an image file on a removable USB disk icon downloads that particular image to related disk.

Figure 1. The Dynamo surface

The Dynamo system supports two levels of user engagement. At its simplest Dynamo provides a public interactive surface that anyone can interact with. All users have access to public areas of the surface and services accessible through the *public palette* (located at the top of the screen). This allows unregistered users to interact with publicly accessible media and devices, or connect up new USB devices and place media on the public areas of the surface. However, users need to register with the system for the ability to more explicitly manage the shared use of the surface through a mechanism called carving.

Carving allows users to appropriate regions of the surface for individual or mediated shared use. Carves can be created by a mouse drag gesture to create privately owned areas in which only the user and their chosen members can interact. Figure 2 (overleaf) shows two carve regions on a portion of the surface. On the right a telepointer passing through a carve region is displayed encased in a bubble, indicating that the telepointer cannot interact with the surrounding carve region or contained windows. The creator of a carve region can invite others into their space by dragging a key icon (located at the top right hand corner of the region) onto the palette of the desired user.

Two further functions that support the extended sharing and display of information are parcels and notes. *Parcels* allow for asynchronous sharing of information. They allow media to be posted up for others and left on the Dynamo surface for extended periods of time in an iconified form. They enable multiple media items to be grouped

together and sealed up on the surface to enable other specified users to open them. *Notes* enable textual information to be associated with media items on screen, and allow asynchronous discussions to occur at the surface.

Figure 2. Two carve regions on the Dynamo surface

4. THE USER STUDY

The Dynamo interaction model has been refined through a user-centred design process with formative evaluation of individual interaction mechanisms [13]. Our next step in this process was to deploy Dynamo in a real-world setting. We wanted to find a communal setting that was used by a large group of people who interacted regularly with each other for a variety of purposes (and who were not members of our research community). A main motivation was to explore how a peripatetic community of people who move in and out of their shared physical space – that has its own cultural identity and existing configuration of technologies and artefacts - relate to, take up, and accommodate a new technology. We were particularly interested in whether the community would use Dynamo to publicly exchange, show and share an assortment of digital media (e.g., photos, video clips, web pages) in social, fun and collaborative ways.

We explored various deployment options such as an office for a nomadic team of audio-visual technicians (one of the preliminary studies informing the design of the system had taken place in such a setting [21]), a student volunteer's room at a conference, and a common room for a student union newspaper team on campus. Access was finally negotiated to a high school common room used by a community of students. This space particularly appealed to us because it was used to support a peripatetic community of people and a broad range of social activities (see section 4.1).

We were interested in studying the extent to which the students would use the Dynamo surface, how frequently and for what purposes. We were also interested in the social conventions that arise when using the shared surface within their own setting.

A key question when carrying out user studies of technology adoption is how long to observe them for. This obviously depends on the focus of the research; previous studies of public displays have varied from short-term (a few hours, a day) to longer-term periods (several months or even years). Typically, short studies focus on usability and interaction issues, such as investigating the efficacy of gesture-based interactions or the coordination of small co-located groups while collaborating around a shared display (e.g., [23]). Studies that are carried out over longer periods have tended to focus on trends, such as the persistence and decline of various social practices when provided with a new technology (e.g., [2, 7]). The focus of our study was to examine the initial adoption and social effects that arise when a new technology is introduced into an established communal setting. As mentioned earlier a key factor for the successful adoption of large surfaces, that involve voluntary use, is the way they are initially perceived by members of the targeted community with respect to how they can be used to their advantage and effect. In view of this, we conducted a two-week study that enabled us to examine the evolving patterns of adoption and social interaction during the initial period of deployment.

4.1. The Setting

We deployed the Dynamo system in a common room provided to 17-19 year old (6th form) high school students as a place to socialize between classes. A number of different approaches were used to understand the setting and to collect information:

- A brief ethnographic study was undertaken prior to the deployment to understand the nature of the space and to consider its suitability as a place of deployment.
- System interactions were logged throughout the study to capture users' direct interactions with the Dynamo system.
- Two researchers were present to study system use throughout the deployment and were available to answer questions.
- Two fixed video cameras captured interactions around the system, one focusing on the screen, the other capturing the room view. These were supplemented by the intermittent use of a hand-held camera.
- A questionnaire was also distributed to the students to collect details and views from them.

The following section describes the common room and the use of the space prior to the introduction of Dynamo. In the subsequent section we describe the findings from the user study.

4.1.1. The Common Room Space and its Inhabitants

The layout of the common room is depicted in Figure 3. There is one entrance to the room. The space includes:

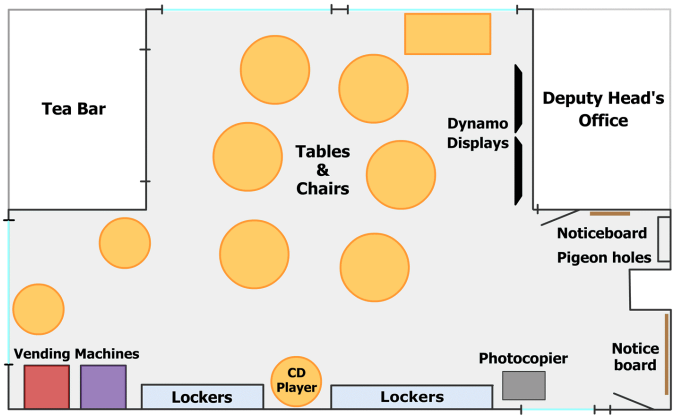

Figure 3: Layout of the common room

- Table and chairs that are moved around regularly within the room by students to provide for different social groupings and activities.
- One hundred lockers along one wall of the space that give students a place to store their possessions.

- Vending machines and a staffed tea bar allowing students to purchase food and beverages.
- A photocopier available to students and staff.
- Noticeboards beside the entrance for students and staff to pin up posters and notes for others.
- A CD player allowing students to play any CDs that they bring to the common room.
- The deputy head teacher's office, which can be accessed without entering the main area of the common room.

There were 150 students in the 6th form; most of the students had been together at the high school for a number of years and so knew each other relatively well, although obviously some were better friends than others. There was considerable movement in and out of the room during the course of any day. In the period prior to the Dynamo deployment, we observed up to 20 students (at any given period) spending time in the common room between classes and at breaks.

The students made use of the space for a variety of purposes. They would hang out with friends in free periods, sometimes doing schoolwork, but mostly socialising. Often they would be in small groups sitting or standing around the tables, and occasionally sitting on their own. We saw instances where students staged spontaneous activities and performances, such as playing a guitar. They also brought in CDs and played them in the room on the shared CD player. A preliminary survey showed a high level of personal device ownership, with mobile phones being most popular, and digital still cameras, USB and zip disks and MP3 walkmans the next most commonly owned devices. We observed instances of students passing around their digital cameras to show others photos they had recently taken. We also observed students sending each other photos via their MMS mobile phones. The students reported high use of email and IM for communication and media sharing.

Our analysis of the common room use prior to the Dynamo deployment indicated a number of patterns of how the communal space was used. Firstly, there was a clear sense of *collective ownership of, and responsibility for, the common room*. The room, the furnishings and resources such as the CD player were not explicitly owned by any one person and there was no formal booking system for their use. They were shared resources that were used by any person at any time. The students relied on social conventions to negotiate use when needed, e.g., to play a particular song on the CD player or to turn the volume up or down. They tended to do this by calling out to others in the room and gauging collective opinion. The management of the room as a collective resource was also socially negotiated, an example being a sign on the wall asking people to "respect the common room and use the bins provided".

The set of resources did not presuppose any particular use or purpose beyond offering *generic functionality*, e.g., for putting things on, sitting on, and playing music on. How the furniture was arranged or re-arranged, what got put onto surfaces, who sat on which chairs, and what music was played when and by whom, were all worked out anew in each instance of engagement with the resources.

Around these shared resources, there was a constantly changing array of *personal 'stuff'* that students brought in and out of the room with them; stuff such as books, CDs, guitars, cameras, bags, and jackets. The ways in which students brought in and arranged these physical artefacts on the tables or in their lockers personalized the communal resources for specific purposes for a given period of time.

The appropriation and consequent personal or shared use of resources happened in a very *lightweight way*, as easily as someone pulling something out of a bag or a pocket. During two hours, for example, one table was brought into play in multiple ways with different configurations of people and stuff: as a private reading space for one, a social committee meeting space, a surface for playing cards on, a homework collaboration table, and a display surface for photos being shared and shown around.

4.1.2. The Dynamo Deployment

For the deployment of Dynamo, we positioned two 50-inch plasma screens side-by-side against a previously unused wall, as shown in Figure 3 and depicted in Figure 4. We also provided three wireless keyboards and mice for multi-user input.

Figure 4: The Dynamo surface within the communal space

The students were introduced to the Dynamo system in a number of ways. Instruction leaflets were distributed describing Dynamo's functionality to the students. They were given a broad introduction to the Dynamo system at the beginning of deployment. Various seeding activities were also provided. For example, in the week prior to deployment, a number of students were given a digital camera to take photos that were placed on the surface. A teacher also scanned coursework-related images and provided 'challenging' questions for discussion. Finally, USB pen-drives were available to loan or buy to allow the students to take media to and from the surface.

5. DYNAMO IN USE

During the two-week deployment, the use of Dynamo varied considerably: students displayed and exchanged photos, video and music, which they had created themselves or brought in from home, they contributed to a pool of public media and left parcels as private gifts for specific people, they gave entertaining shows to audiences, posted notices for others, played together on the surface, and engaged side-by-side in group discussions and interactions. In the following sections we explore in more detail the particular nature of the students' use of Dynamo in terms of both the direct interactions with the Dynamo system and the interactions in the common room around the Dynamo system.

5.1. Interaction with the Dynamo Surface

The system was deployed for a total of ten days from late Friday afternoon to Thursday evening. The room was available to students Monday to Friday from 8.30 to 5.30. Throughout the study we logged a number of different types of user interactions, including:

- Plugging a device in or out
- Dragging media onto and off the surface via palettes
- Creating, moving and resizing windows for media, parcels, notes and carves.
- Interacting with windows using toolbars and scrollbars.

Based upon these high-level actions, a density of interaction over the course of each of the 10 days of deployment can be generated (Figure 5). The value in each cell indicates the number of discrete interactions as logged by the system for a particular time slot. It is worth noting how the general rhythm of use followed the overall daily timetable with usage peaking around the morning break and lunch time. The usage on Day 5 reflects a fieldtrip day without classes, with a significant number of students (who did not attend the fieldtrip) spending most of the day in the common room.

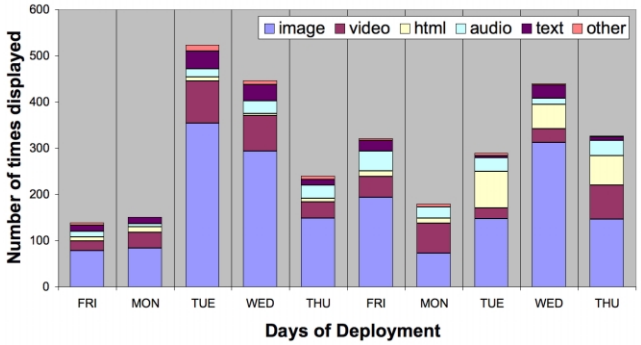

Figure 6: Media displayed on the Dynamo surface

During the course of deployment students used the surface to display a wide variety of media. Figure 6 shows the types of media displayed on the surface. Internet connectivity was limited in the first week due to networking issues, which explains the upsurge of HTML content displayed in the second week. Images and video were the most popular types of media displayed. The availability of digital cameras that could easily be connected via USB encouraged students to generate this form of content. Most of this media was created on the fly by students for their friends and tended to be a lot more popular than displaying media from the web and other places.

Audio (created by music students and various school bands) tended to be as popular as images and videos to download from Dynamo, as shown in Figure 7. Many of these downloads reflected a negotiated exchange where one student would either offer or request the media from another. Students would often use the surface solely for the purpose of exchange. A number of the items, including a popular PowerPoint file and a series of entertaining images, were left on the surface as a communal resource that could be downloaded by anyone.

In addition to logging the movement of media we also logged the use of the mechanisms provided by Dynamo. Figure 8 shows the number of times the system features of parcels, carving, and notes were used. For parcels this is the number of times a new parcel was created, or an existing sealed parcel was opened. For notes this was the number of times a note window was created on screen and typed into. For carving this was the number of times a user carved a region and added a window (or set of windows) to it.

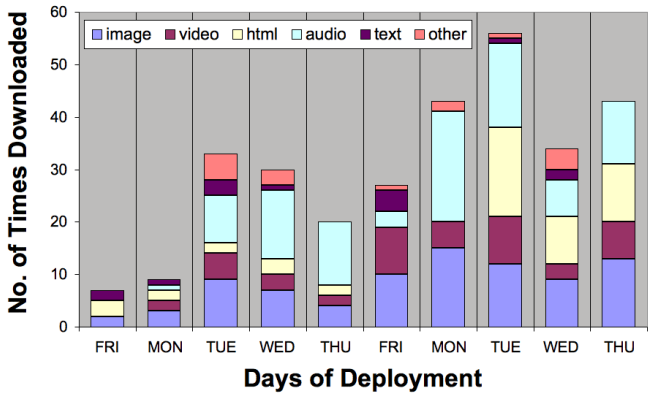

Figure 7: Media downloaded from the Dynamo surface

Students experimented with notes straight away and used them fairly consistently throughout the course of deployment. Carving was used more frequently in the first week than in the second, as users developed a better understanding of this feature. In the first week, carving was often used as a mechanism to play and socialize with others - by either carving over another user's active window or carving over the free space on screen to deny access to others. This unanticipated and playful usage helped users strengthen their familiarity with this feature. By the second week carves were used in more targeted ways, when users found a genuine need to control access to shared content such as public notices and images. In comparison, the adoption of parcels was much slower. As shown in Figure 8, parcels were used more in the second week, when the students became more aware about keeping items available and avoiding on-screen clutter.

Some interesting patterns of parcel usage emerged when examining the log files in more detail. We calculated the duration in minutes that distinct media files were viewed on the surface, grouped these by format, i.e., image, video, PowerPoint etc, and by the source, i.e., whether media file came from a parcel, palette, web etc, and then calculated averages. In Figure 9, we see one particular example illustrating the average duration in minutes that image files were displayed per day. In the first two days, images were displayed on the surface in a fairly ephemeral manner. The duration images remain on the surface steadily increases in the first week because students had filtered out the popular photos and these remained on the surface for longer. However, even at its peak these photos do not remain on the surface for long (less than 1 hour). We observed that

	Friday Day 1	Mon Day2	Tues Day3	Wed Day4	Thur Day5	Fri Day6	Mon Day7	Tue Day8	Wed Day9	Thur Day10
8:30-8:50 (registration)	0	0	0	0	0	0	0	0	0	0
8:50-9:50 (period 1)	0	112	231	177	218	0	0	0	0	0
9:50-10-50(period 2)	0	76	135	129	285	0	0	0	336	0
10:50-11:10(break)	0	213	492	552	273	122	272	497	356	335
11:10-12:10(period 3)	0	107	414	193	364	162	197	156	126	139
12:10-1:10(period 4)	0	139	378	263	249	293	361	482	939	637
1:10-1:50 (lunch)	0	487	976	762	244	537	422	172	1183	769
1:50-2:50 (period 5)	0	189	635	235	212	0	0	454	725	562
2:50-3:50 (after hours)	178	274	329	129	294	92	139	344	501	308
3:50-4:50 (after hours)	237	191	149	83	12	0	0	0	0	266
4:50-5:50 (after hours)	412	14	19	17	0	0	0	0	0	124

Figure 5: Aggregate usage through the study (numbers refer to direct interactions as defined in section 5.1)

students would often get frustrated when they returned to the surface and found their pictures had disappeared.

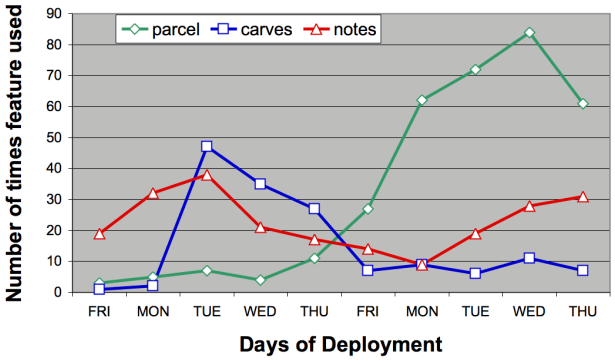

Figure 8: The use of Dynamo surface features

This led students to experiment with parcels, with some evidence of parcel usage in the first week. In the second week, we saw a considerable change in the data. This coincides with students' adoption of parcels for grouping, organizing, and persisting images up on the surface so that they could be shared asynchronously. In general, in the second week, we found that a lot more of the students were using parcels to group and keep their media, in particular images, video and audio. One could infer that students had initially seen the surface as a synchronous tool affording the rapid display and exchange of media whereas, in the second week, the students had started to discover the asynchronous nature of the system and its ability to make media persistent and provide noticeboard style functionality.

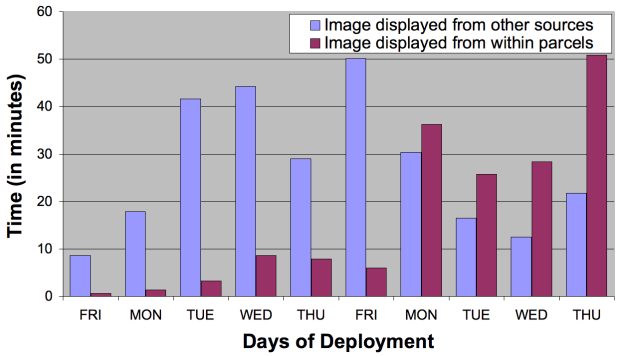

Figure 9: Average duration that images were displayed for

5.2. Dynamo in a Communal Setting

The information captured in the log data tells only part of the story during deployment. Interaction drew as much upon the nature of the space as the facilities provided by the surface. Students interacting with Dynamo through interaction points (keyboard/mouse pairs) tended to use the tables closest to the screens. As this spatial orientation became understood, others would choose to gather nearby to watch or participate indirectly. The openness of the space and the visibility of the screens meant that people were able to engage indirectly from anywhere in the room however. For example, people would often sit on the back tables and join-in occasionally with on screen interactions. This became a critical factor in the interplay of Dynamo and the room.

In the following vignettes, transcribed from video segments and observational notes, we describe how people drew upon these spatial arrangements in conjunction with Dynamo, making use of the normal rhythms and flow of movement in the space.

5.2.1. Drawing Others In

This first vignette presents a typical interaction around Dynamo:

> *Mike (second from left in Figure 10) goes through items from his pen drive and from the parcels on Dynamo. For the next 15 minutes, people come in and out of the room, and occasionally chat to him about the visual material on-screen. Shortly, two groups gather on two of the back tables (right of Figure 10). Mike opens up a series of items, spreading them out across the screen: these include MP3s and some photos. He then opens a PowerPoint show containing a series of visual illusions. As he goes through each slide, he turns to the others in the room, gauging their reactions and engaging his friend sitting next to him in banter:*
>
> *'That's quality!' 'Oh yeah, it is very good, yeah'…*
>
> *'Do you have any more like that?'*
>
> *Soon the others in the room become an audience, watching keenly and discussing the illusions amongst themselves. During the show, some others arrive and watch whilst still standing, and contributing verbally ('ahh – oh mate, I love those ones!'). When the slides finish, Mike then puts on some music, and opens some photos, up-sizing each one consecutively, and each time getting an audience reaction. He then proceeds to go through the parcels, looking at photos and leaving some open down the right and left sides of the surface. He leaves his PowerPoint show in a public parcel when he finishes.*

Figure 10: Mike (pictured front left), performing to the room

The very position of Mike at the table indicates an orientation to both the surface and to the rest of the room. While he is going through his material on his own, the fact that it is being done on a public surface invites people to chat with him about it. His actions in increasing the size of the objects on the screen and in turning to gauge people's reactions serve to indicate further that he is producing these objects for the enjoyment of others as well. This *upsizing* of objects was a recurrent theme in the use of Dynamo. This turns a more personal engagement with Dynamo into a public one. People all over the room can be drawn in to his show. Moreover, by browsing through existing parcels and putting the PowerPoint presentation in a parcel he is selecting material of interest and making it into a communal resource for others.

5.2.2. Staging a Performance

At other times Dynamo was used to draw in larger audiences for more performance-oriented uses, especially making use of known busy times in the common room.

In Figure 11, a large number of students have gathered in the common room at lunchtime because word had passed around that Leo had captured some funny video clips earlier that day of different students performing. These videos were played in an up-sized

window on the Dynamo surface with much accompanying laughter and banter.

Figure 11: Drawing the crowd around Dynamo

Here, the common room together with Dynamo has been used as a public performance space and the students play out this understanding implicitly in the way they orientate themselves to the screen. As in many other instances when students staged similar 'performances', these homemade video screenings were treated as sources of entertainment and fun.

5.2.3. Interweaved Engagement

These aspects of drawing others into some engagement around Dynamo, upsizing media, and anticipating the movements of people played out in many different ways, beyond just performance use, over the two weeks. Often two or three people would be interacting with Dynamo at the same time, and without any explicit negotiation, one would take over the surface for a while before moving back to their parallel or collaborative use, as illustrated in the following vignette:

Figure 12: Peter (left) showing a photo to Charlotte (right)

It is lesson changeover. Peter has been talking with Gemma and Heather who are interacting side by side with Dynamo when he looks up and sees Charlotte in a group of girls at the lockers about to move on to class. (As pictured in Figure 12)

Peter, turning to Charlotte: 'Charlotte, I've got that song … I've also… got a really big picture of Justin, on stage, in the middle, sittin' down. I'll show you.'

The girls stop and turn to face Dynamo. Meanwhile, Gemma, interacting in another area of Dynamo, starts a conversation with Crispin who is at the tea bar.

Gemma: 'Crispin! There's a picture of you on here'
Crispin: 'Where?'
Peter to Gemma: 'Are you using it [closest keyboard]?'
Peter to Charlotte: 'Wait! I'll show you!'
Peter walks over to the USB hub to insert his pen-drive.
Meanwhile Heather has found the picture of Crispin that Gemma was talking about and makes it really big, covering a third of the right screen, opposite where they are sitting.
Crispin: 'Oh my lord!'
Peter, logging in and getting ready: 'Are you ready for this Charlotte? … Are you ready for this?'
Peter opens the picture up and expands it to more than half the surface, in place of where Heather's photo of Crispin was.
Charlotte: 'Ahhhhhh! I love him'.
Crispin: (interrupts): 'Who's that?'
Peter: 'It's Mister JT'
Then Charlotte and her friends filter out of the room, one of them saying 'we're late!'

Here Peter, Gemma and Heather have coordinated their use of the surface to be able to produce actions for two different parties at the same time: Gemma and Heather show Crispin a photo, while Peter shows Charlotte and her friends a different photo, each engaging their audience in conversation. As Crispin, Charlotte and her friends pass through the room Peter, Gemma and Heather make opportunistic use of their presence. They invite their intended audience to pause and look at the screen, signalling which objects to look at by upsizing them. The audience do not move closer to the screen, and in doing so signal that they are in a hurry and are just stopping briefly to watch. There is also little explicit coordination between Peter, Gemma and Heather about where and when they show their photos on the surface.

6. DISCUSSION

As stated previously, the focus of the study was to examine the adoption and social effects when a new technology is introduced into an established communal setting. In this section, we discuss the student's reactions to the system in use, show how their use of the system mirrored their use of the communal space itself, and explore some of the reasons for the high level of uptake in this initial period of use. We go on to highlight some design implications for interactive surfaces within communal settings.

The majority of the students were enthusiastic about the Dynamo system, although there was a small minority who found the system to be distracting and intrusive in their space. They found it easy to share and exchange digital information with others via Dynamo for both social and more pragmatic purposes. The students reported that it promoted a social atmosphere and generated opportunities for people to engage with others that they wouldn't normally talk to. The media that they were able to show on the surface was a trigger for much of this talk and social engagement, as also found by others, e.g., [5, 15]. These effects are reflected in some of the comments from the students in an end of study questionnaire:

"It was fun"; "A new and useful way to bring the high school community together"; "It made the common room more interesting and a lot more crowded."; "A lot more people spent time in the common room"; "Caused more people to socialize"; "Brought everyone together." [1]

"It did actually bring students together so we could share funny videos etc."; "Adding photos and sharing things meant you spoke to people you wouldn't usually"; "An effective way to transfer and share information."; "Enabled people to share fun things that they had made"; "Good to be able to leave messages and swap photos."

Analysis of the observed patterns of interaction and the captured system logs, discussed in Section 5.1, demonstrates the various ways in which the social effects of Dynamo played out. Of particular interest is how students were able to exploit Dynamo as a communal surface in much the same way as they appropriated the common room as a communal space, as discussed in Section 4.1.1. As well as being seen as 'just another shared resource' Dynamo allowed their lived experience of communality to be played out on the shared surface, providing novel ways of doing familiar things with different digital media and devices.

[1] Head counts from before and during the study confirmed increased use of the common room.

The vignettes in the previous section illustrate the extent to which the common room implied a context that helped shape the interaction with the Dynamo surface. Many of the features that characterised the common room as a communal space were reflected in the use of the Dynamo surface.

The common room offered a level of *visibility and availability* that was drawn upon by inhabitants in their interaction with Dynamo. Similarly inhabitants exploited the large display to make their *actions more publicly visible and cause digital media to be more available* to others. When placed on the surface media and actions associated with it became visible from all parts of the room, especially when compared to tabletops or digital camera screens. There was an ease with which the students moved between direct conversations, peripheral observation of others' activities, and interjections from a distance – from being alone to engaging in a small group or with the larger room.

The common room was *collectively owned* by its inhabitants. It was clear from the beginning that the students also regarded Dynamo as *their surface*. A telling illustration of this was when a teacher came in and put up a notice on the Dynamo surface about a concert he was performing in. As soon as the teacher left, one of the students removed the notice from view. While students occasionally closed other students' public windows, they did so either by accident or with a sense of play. More often, public parcels and items that looked like purposeful notices were left in place by the students or moved to the side rather than closed.

The common room was *communally used* by its inhabitants. Similarly, the students understood the surface as being collectively owned and *communally used*. They would move around the three interaction points to suit the interactions in hand, and there was never any hesitation observed among the students in picking one up if it was free. Sometimes they would position themselves next to someone else already using Dynamo, especially if this person was a friend. Other times they would take up a place at a different table – just as they would if they were doing some other activity. Sometimes they engaged in parallel interactions with digital objects in different regions of the surface, usually choosing an area directly in front of them. Students also engaged in banter and play with each other on the surface, moving each other's objects about or taking up larger regions for a while.

A set of *social conventions* was clearly in evidence in the common room. A similar set of *social conventions* developed around Dynamo, reflecting an understanding of collective ownership and shared use. Conventions were quick to develop about managing the surface as a communal space. One day, for example, Leo left open a locked web browser window up when he left the room. As soon as he came back a little later, the people who were then using the surface asked him to remove this window. One person, Gemma, took on a particular role as the 'policeman' of the communal surface, watching for the return of space wasters and asking them to remove items that were blocking other people from using the surface. In another instance, Heather and Frank were 'playing' together on the surface when Frank closed one of Heather's window – Frank was registered so had greater access control over his resources than Heather who was not registered. She called out "Hey that's so rude!" and decided then to buy a USB pen drive and become a registered user herself so that she could prevent this happening again.

The common room was routinely *appropriated by its inhabitants*. Similarly, the students *appropriated the functionality* of the surface in ways consistent with their use of the common room but not as we had anticipated. For example, we had expected that the students would respond to the photos and questions provided by the teacher (as one of our seeding activities) by leaving notes with comments but they tended to use notes to leave jokes and messages for each other. In a similar way, we had thought that the students would use the sharing capabilities of the surface to exchange study files but instead they exchanged their own homemade music files, photos and videos.

The common room supported *different levels of personalization* by allowing students to bring items into the space and providing secure lockers. The importance of *personalization* was reflected in the media brought to the surface. Students interacted mostly with digital resources that they and their friends had gathered or produced. Leo, for example, put considerable effort one evening to make a home video of his friends skateboarding, so that he could bring it in and show it on the Dynamo surface. There were many examples of this kind of explicit activity. The students also learnt to make use of parcels to leave artefacts on the surface for more extended periods of time, sometimes for their own use, but most often to be available for others.

The *nature of the common room changed throughout the day* reflecting the rhythms of the timetable. The use of Dynamo also reflected the rhythms of the day as previously discussed with respect to Figure 5. In this variability, the surface became a different type of place depending on who was using it, what they had brought to the surface, how many people where interacting at the same time and the level of involvement of people elsewhere in the room in terms of their activities and orientations. It became a place for socialising, for individuals enticing others to socialise with them or giving shows to audiences, for groups chatting and closely interacting on the surface, for brief opportunistic exchanges between passing friends, or in quite periods simply a place for an individual to pass time and review media on the surface.

6.1. Initial Adoption Lessons

In this initial deployment period, we witnessed a high level of adoption of the Dynamo surface, where it was interleaved with the everyday practices of the community within the common room. While the longer-term effects are open to further investigation, we would suggest a number of design factors contributed to these initial adoption effects.

Firstly, the students were able to engage with the system via different levels of interaction thus enabling *'graceful' buy-in*. The interaction points (each comprising of wireless keyboard and mouse) provided familiar ways of interacting with the surface. Anyone could take control of an interaction point and immediately start manipulating public media already on the surface or source media by connecting their unregistered USB devices or by accessing the Internet. At a further level of buy-in, students could register their USB devices so that they could log on to the system and have a degree of access control over their own media. This graceful buy-in model made it easy for students such as Heather to try out Dynamo with minimal effort and to choose when they wanted to increase their buy-in up to full registration. One main outcome was the facilitation of unplanned and opportunistic use. For example, on seeing an interaction point free, students often seized them to interact with Dynamo.

Secondly, the interplay of the surface in the physical space and the public visibility and availability of Dynamo in the room supported *graceful learning*. Similar to over-the-shoulder learning [26] it was

easy for students to sit and watch others using the system. This was important for those students who were not comfortable learning in front of their peers. We also often saw back seat tutoring from people who never actually used the system directly but who had learnt from watching. Other students made use of known quiet times to try out the system when there wouldn't be many people around, thus also avoiding social embarrassment.

Thirdly, there was evidence of *discretionary engagement* in terms of levels of interaction with the system. As shown in the vignettes, some students interacted directly with Dynamo while others would interact indirectly by asking others using the system to do something on their behalf, e.g., to show a photo. They could be casual observers, attending to the screen occasionally or closely engaged with what was going on either up close or from a distance as part of an audience. Transitions between levels of interaction, such as from private to public and single to many, were facilitated by different combinations of body locations in the physical space and the sizing of media on the surface.

Fourthly, the students found the interaction model of *bringing media to the surface and taking it away* simple and easy to understand and accomplish. They were able to use their own portable personal digital devices to interact with the surface and in so doing, frequently collated media from different sources to share with the others. The act of walking up to the USB hub was a public action, signalling to others that there might be something interesting to have a look at.

Finally, the students quickly understood the *sociable and open approach to the sharing and exchange* of information that the public surface enabled. While the students were already familiar with sharing and exchange of digital information, e.g., using email attachments or passing around photos, they discovered it was easier, more flexible and sociable using Dynamo. For example, people often brought in media sourced from digital cameras and emails and left these up visible on the surface as public resources, promoting an open forum for discussion and allowing others to freely download them.

6.2. Implications for Design

Obviously, the extent to which Dynamo might serve to equally support and augment other communal settings is open to further investigation, especially to understand how the same generic mechanisms and communal surface might be appropriated for different uses. In this setting the students already knew each other and had established practices in the space and these were reflected in the surface. Our study provides some initial insights and implications for the design of interactive displays for communal use. These include:

The interactive display should fit in and be able to be integrated with the other artefacts used in the space. In this case the interactive surface mirrored the shared nature of other surfaces within the space. In particular, the multi-user properties of the digital surface allow it to be used as a communal resource.

Provide flexibility both in terms of physical and digital arrangements: Communal spaces are configurable. They contain different artefacts that can be moved around and rearranged to suit the community of people. When developing interactive display systems it is important to consider these properties of the physical space and allow the technology to also be rearranged and reconfigured by its users. For example, Dynamo was flexible in terms of the personal devices it supported, allowing users to choose the different configurations that they required.

Design interactive applications that the community can adapt to their own activities: When designing for such general-purpose and diverse social spaces it is important not to overly structure interactive applications for particular activities or use. For example, our attempts to promote use by placing seeding media based around student assignments and what we considered interesting images failed because students found them contrived.

Provide an initial set of display-based interactions that are intuitive and can be easily and comfortably followed: Allowing users to engage with the display, without needing help or feeling self conscious, is a key concern when situating displays in communal spaces. For example, the support for graceful buy-in meant that students could gain confidence with the initial set of interactions and then move on to learn the novel Dynamo mechanisms such as carving and parcels to enable more controlled sharing and exchange of media.

7. SUMMARY AND FUTURE WORK

The key contributions of this work are the deployment of a communal surface into a novel setting involving an existing peripatetic community, and the study of an initial adoption period that has often proved difficult for large display systems. Throughout this study, we observed the Dynamo surface being used to display, share and exchange a wide variety of media, which post study log analysis also helps to confirm. There was a high uptake of the various Dynamo functions. The students accomplished familiar activities, such as sharing and exchanging information, passing away time on their own and socialising with friends, in novel ways and with different media. This took place within a communal context with the students integrating Dynamo as a shared resource into their communal space. The students drew upon their understandings of the temporal rhythms and flow within the room, and appropriated the display system in similar ways to how they appropriated the physical space and resources.

As ongoing work, we plan to deploy the Dynamo system in more diverse communal settings for extended periods to study the evolution of use and community effects of such a system in situ over the longer term.

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