

An Investigation into Interactive Display Technologies

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APSC 261

November 28, 2011

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ABSTRACT

There is interest in putting an interactive display board in the new Student Union Building (SUB) at UBC. This report compares in depth various display and interactivity technologies and their respective benefits and disadvantages. This report also covers the optimal location for such a display board given the technology being used.

After ruling out several other technologies, LCD and LED televisions are compared with regards to cost, social consideration, and economic impact. LED TVs are found to be the best choice, as they are cheaper over time and more environmentally friendly.

Several interactive kiosk technologies are compared, including keyboards, mice, trackballs, touch screens, Kinect sensors, and voice command. Under a triple-bottom-line assessment, touch screens are found to be the most favourable, as they are more functional than the other options.

After considering many factors, the walls at the centre of the atrium on the main floor are the best options for display board placement.

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1. INTRODUCTION

To get students involved in sustainability at UBC, the New SUB Design Committee want a way to showcase the energy and resource usage of the new SUB. To meet this need, they decided that some form of interactive display board would be an excellent way of getting students involved. Students would be able to see the power that their building uses. They could see their contribution and what actions they could take to improve the environment and reduce human impact.

To maximize student involvement, viewability and interactivity must be optimized by choosing the best technologies for the task. Some technologies are more expensive but are more useable. Others are extremely inexpensive but will not succeed at garnering student interest. Thus the difficulty lies in striking a decent balance between social impact and cost. This report compares a number of different technologies for both display board and interactivity type and makes recommendations for each. The report also considers an ideal placement for the display board, as to further optimize viewability and interactivity.

2. A COMPARISON OF NON-INTERACTIVE DISPLAY TYPES

2.1 Introduction to Non-Interactive Display Types

There are two main types of displays being considered for the new SUB; projectors and television screens. Each has their own unique properties, which determine their suitability for this application. There are many forms of video projectors, the most common being the LCD projector, which will be examined here. Plasma, LCD, and LED were the three types of television screens proposed for further research.

Plasma screens work by having millions of tiny cells that contain noble gases and mercury. An applied voltage across a cell turn the gas into plasma, which through reactions with mercury that is also in the cell, releases a photon. This photon hits the coloured phosphor coating on the cell (red, green, or blue) and visible light in that colour is released; however, most of the energy is shed as heat. This makes plasmas draw a lot more power compared to other display types.

LCD and LED television screens are very similar; in fact LED television screens only differ from LCD screens by their source of light. LCD screens are composed of millions of cells that contain liquid crystals. These liquid crystals have light modulating properties; however, they do not emit light on their own. Each cell contains two polarizing filters, oriented perpendicularly, located at the front and back of the cell with the liquid crystal in the middle. On active-matrix LCD's (the most common type, used in TV's and computer monitors), there is also a matrix of TFT's or diodes that hold the electrical state of the cell (pixel) while the other cells are being changed. LCD screens are backlit by a cold cathode fluorescent lamp behind the LCD panel, as a result they are much more efficient than plasmas regarding energy consumption.

LED screens are in fact LCD based, but they use LED's to backlight the panel instead of cold cathode fluorescent lamps. They are more energy efficient than standard LCD's as a result.

LCD video projectors work very similarly to LCD televisions. A metal halide lamp sends light through prisms or filters that separate the light into three cells, one for each base colour (red, green, and blue). Each cell has a polarizer, and LCD panel; by opening and closing each individual pixel complex images are produced. A large amount of light is needed to display an image, and ambient light is a major factor when considering its application.

2.2 Comparison of LCD and LED Display Technologies

2.2.1 Costs

For a product to be viable, its cost is a major factor to consider; therefore, when choosing a display screen for the new SUB, its cost should be investigated. The economic aspect of the triple bottom-line assessment will be discussed here, comparing costs of the LCD and LED television screens.

As LCD and LED televisions are almost identical in design, an effective method of determining costs is to compare the cost per square inch of display of various sizes of LCD and LED televisions. Assuming that a resolution difference of 720p versus 1080p is negligible for viewing, data from 720p displays is used whenever possible. It was decided the most efficient method of display was to use commercially available television screens. This is because they can be used for individual displays throughout the SUB, or set up in a grid pattern for one large display. Plus if there is a problem with one of the screens, only one television needs to be fixed instead of the whole display.

The following tables (Table 1, Table 2, and Table 3) summarize the data from Sony's consumer website.

Table 1: Cost of LCD Televisions

Screen Size (Diagonal, in)	Cost (\$)	Cost per square inch (\$/in²)
54.6	1799.99	1.41
46	899.99	1.00
40	649.99	0.95
31.5	429.99	1.01

Table 2: Cost of LED Televisions

Screen Size (Diagonal, in)	Cost (\$)	Cost per square inch (\$/in²)
54.6	1849.99	1.45
46	1199.99	1.33
40	925.99	1.35
31.5	679.99	1.60

As a whole, LCD displays are cheaper than LED displays, which is partly due to how new LED backlit displays are made. Both LCD and LED televisions in the 40"-46" range are the cheapest per square inch.

Table 3: Power Consumption of LCD and LED Televisions

LCD Screen Size (in)	Power Consumption (max)	Power per square inch (W/in²)	LED Screen Size (in)	Power Consumption (max)	Power per square inch (W/in²)
54.6	315 W	0.2473	54.6	166 W	0.1303
46	210 W	0.2323	46	103 W	0.1139
40	180 W	0.2633	40	102 W	0.1492
31.5	115 W	0.2712	31.5	77 W	0.1816

Even though LED televisions are around 33-50% more expensive up front than LCD televisions, note how much more efficient they are when it comes to power consumption. Since the light source is the main factor determining when an LCD or LED television will wear out, it will be used as the determining factor for longevity. Assuming the televisions are on for 18 hours a day 7 days a week, this gives 126 hours of use a week. CCFL's from LCD televisions are rated for 20,000 hours, whereas LED televisions can offer up to 80,000 hours on average. This means an LCD television will last approximately 3 years before needing to be replaced, but an LED can last for 12 years. Given that UBC receives its electricity from BC Hydro at \$0.049/kWh with a nominal growth of 3.9%, and using the 46" television screen size as a basis (being the cheapest in both initial cost and running cost), over a 3 year runtime the LED television saves \$107 in running costs per television. Coupled with the fact that LED televisions last on average 3 times longer than LCD televisions, LED televisions are the best candidate in terms of cost.

2.2.2 Environmental Impact

When considering environmental factors, the two television types share many design characteristics. Packaging, transportation, and the plastic shell and glass that surround the internal components are virtually identical. The only major difference between LCD and LED televisions is their backlighting source, and therefore their power consumption and lifespan. Looking into their backlighting, LCD televisions use CCFL's whereas LED televisions use LED's.

A CCFL is composed of a sealed glass tube with electrodes at either end. Inside the tube is a phosphor coating and an inert gas with a slight amount of mercury. Mercury is a heavy metal and is damaging to the environment, so proper disposal or recycling is required. Many manufacturers have reduced the amount of waste mercury from CCFL's by 60% on average by separation and reuse. The rest of this waste is sent to industrial waste disposal dealers for transportation and disposal. In 2004, the total mercury used and produced in Taiwan was 886 kg and 224 kg of it was not waste treated afterwards. Of the 224 kg that was not treated, 199 kg of it was contained in CCFL's (Chang, You, Yu & Kong, 2006). The glass tube is recyclable, and the inert gases will not react when disposed. To create the inert gas used in the bulb, a common practice is to use a technique called "liquefaction of gases;" air is cooled until the gases condensate where they can be separated using distillation and other methods. This requires a lot of energy to cool and pressurize the gas, adding to the embodied energy in the CCFL.

An LED is composed of thin layers of semiconductor material in a glass or plastic bulb. These semiconductors are typically compounds of gallium or silicon with impurities of zinc or nitrogen added. These semiconductors last significantly longer than their CCFL counterparts. However, the production of silicon wafers, and therefore semiconductors, requires a large

amount of harmful chemicals and water; "On average, the manufacturing of just 1/8-inch of a silicon wafer requires about 3,787 gallons of wastewater, not to mention 27 pounds of chemicals and 29 cubic feet of hazardous gases" (Holden & Kelty, 2005).

Table 4: Substances used in manufacturing of LCD and LED televisions

Substance	Effects/Dangers	Which display has less/none of this substance	
		LCD	LED
Mercury	Toxic to living organisms, heavy metal		X
Semiconductors	Require a large amount of raw materials, harmful chemicals, and energy to make	X	
Inert gases	Require energy to create		X

Both LCD and LED television manufacturing produce waste, with "packaging materials of delivered parts and components account[ing] for about 80% of waste generated" (Toshiba, 2011). Another similarity between the two television types is that both processes create large amounts of wastewater that is high in phosphoric acid; Toshiba has come up with a solution to reuse much of this water as a raw material for fertilizer.

In comparison, the LED television gains an advantage because while both types contain semiconductors, LCD televisions contain more mercury. Adding the energy required in the production of the noble gases used in the CCFL bulbs and the fact that LCD televisions do not last as long, LED televisions are the environmental choice.

2.2.3 Social Impact

Again, since the backlighting source is the only difference between LCD and LED televisions, this will be the area of interest for investigation regarding social implications. These technologies will be examined to determine if there are any ethical or health implications in their production, as well as how it affects students at UBC.

In the manufacturing of LED's for LED and LCD televisions, there is much concern for the safety of the workers. At semiconductor production facilities, workers are required to wear full body suits and use harmful chemicals, many of which are known carcinogens. These suits do not protect the wearer however; "They protect the silicon wafers from the people, not the people from the chemicals" (Holden & Kelty, 2005). Workers have to use chemicals and products such as lead, arsenic, and toluene which have very serious side effects. In the past, companies have had major problems with employees receiving long term exposure to these substances, however the safety of the workers is still a current issue.

In terms of raising awareness of sustainability at the SUB, the edge goes to LED televisions however slight. As both displays are sleek and modern, to the average viewer they both portray a similar image. Nevertheless, an LED television uses less power and thus as long as people are aware of this they will see sustainability as a positive outlook with attractive features. A benefit of using a commercially available product such as LCD and LED televisions is that students and viewers can easily visualize how much the displays cost and what goes into them. Using multiple displays scattered throughout the SUB allows for a larger population of students and users of the building to view the displays, thus improving awareness of sustainability.

2.3 Recommendations

After studying the economic, environmental, and social factors in the non-interactive display types, LED televisions are the best choice. From an economic standpoint, LCD televisions are cheaper up front, but are more costly in their use. More frequent replacement as well as consuming a larger amount of power adds to the cost of LCD televisions. This makes LED televisions the best choice in the long run. Environmentally, LED televisions gain a slight advantage. While LED televisions use a large amount of semiconductors which require copious amounts of water and chemicals, LCD televisions also have them to a lesser extent. In contrast, LCD televisions contain a higher amount of mercury and inert gases which each have their problems. In terms of social impact, LCD and LED televisions are fairly equal. Semiconductor production has issues regarding the safety of the workers. However, LED televisions are newer and more energy efficient which will have a greater effect on the viewers of the screen. A majority of these viewers will see the importance of sustainability from the type of display used.

3. A COMPARISON OF INTERACTIVE KIOSK TECHNOLOGIES

3.1 Introduction of Interactive Kiosk Technologies

One major reason for the display board is to get students involved in thinking about sustainability at UBC. If students have a quick and easy way to learn a bit about the way the SUB is run in terms of energy and resource use, perhaps they will change their ways and take the ideas of sustainability with them. This section discusses the possibility of direct interaction with the display board. As an interactive display, the new display board will effectively be a kiosk. In order to engage students, the board must be able to attract their attention and entertain them long enough to teach them an interesting fact about sustainability and/or the new SUB. We discuss the following interactivity technologies: the keyboard, mouse, touch screen, trackball, and Microsoft Kinect.

Keyboard:

The keyboard and mouse are very common devices used for interfacing with computers. Keyboards and mice are mostly made of plastic with a few electronic components inside. They are relatively cheap and can be recycled with little effort. Keyboards are effective when a device needs a lot of information from the user, since they are capable of rapidly taking in keystrokes. Mice are useful when the user needs to select something on the screen.

Touch screen:

Touch screens are a fairly new technology. Since most students have used a touch screen enabled cell phone or other device, they are probably familiar most with this kind of technology. Touch screens find themselves integrated with display types. As they are a minor extension,

size-wise, to a display, their environmental impact is negligible compared to their use.

Compared to other input technologies, they are rather expensive. Touch screens are effective when a device needs quick, but small amounts of input from the user, so they are commonly used in kiosks.

Trackball:

Trackballs are an older, mostly defunct technology. Like the mouse, they act as a point-and-click interface to a computer or kiosk. They work by having a ball in a socket which the user rolls around to manipulate a pointer on a screen. They share a similar cost with mice and are made of mostly the same materials. However, unlike mice they are far more durable, as only the ball moves instead of the entire device. In addition, they don't have to have a wire exposed to the user. Thus they are a common input method for kiosks. However, students are less likely to be familiar with a trackball as they are less common.

Microsoft Kinect:

The Microsoft Kinect is a fairly new technology originally used with the Xbox 360 gaming system. Due to its open nature, it has been adapted for other uses. In essence, it is a camera paired with a distance sensor, capable of measuring users' body movements. The user does not have to directly touch the device. Kinects are cheaper than touch screens but more expensive than mice and keyboards. However, as a new technology, they must be programmed, as discussed later on. Kinects are not typically used in kiosks but can be adapted to most situations.

3.2 Comparison of Touch Screen and Keyboard Interfaces

3.2.1 Costs

Each of the respective technologies has a certain initial cost and maintenance fee. Table 5 below is a table summarizing the initial costs of each technology being considered and their maintenance fees.

Table 5: Interactive Technology Cost Comparison

Type	Initial Cost	Durability (years)	Projected 10 year cost
Mouse	\$15	1	\$150
Keyboard (mechanical)	\$150	5	\$300
Touch Screen	\$1000	5	\$2000
Trackball	\$50	5	\$100
Kinect	~\$12000	~15	~\$12000

Costs for each device are based on current consumer pricing. For specialized kiosk versions, prices are roughly double and require specialized quotes from each company.

Keyboard durability is based on keystroke usage. Mice durability is estimated to be small because it has an open cord. Note that these costs are on a per-screen- basis. Each kiosk will only need one form of input. Even the large display will only have one touch panel at the bottom.

The Kinect is a special case for cost. Due to its experimental nature, a programmer will need to be hired to create the interface for the display board. This should take around 4 months for the average co-op student. Thus an initial fee of \$12000 is required. After this, the Kinect will not need to be replaced. Since it has no moving parts and nothing that heats up, they theoretically last an extremely long time.

We chose a mechanical keyboard for cost/maintenance purposes because after looking at statistics, it proved to be the cheapest over 10 years. Keyboard durability was estimated based

on usage. The average mechanical keyboard can withstand 35 million keystrokes. As the average user types at 40wpm, and the keyboard is used around one fifth of the time, a little math reveals an approximate durability of 5 years. There are three keyboard types: membrane, mechanical, and scissor-switch. Membrane keyboards cost around \$30 and last for 5 million keystrokes, and scissor-switch keyboards cost around \$50 and last for 10 million keystrokes. As mechanical keyboards are more comfortable than membrane keyboards, and cost less in the long run than the others, they are the clear winner.

As can clearly be seen by the table, the Kinect is the most expensive option, followed by touch screens, and then keyboards and then mice. Most often, keyboards will need to be paired with a mouse/trackball to be the most useful, so their costs should be combined.

3.2.2 Environmental Impact

In terms of environmental impact, each technology is roughly the same. Keyboards, mice, trackballs, and monitors all can be recycled. As they last for years each, there is an almost insignificant impact on the environment. The same goes for a Kinect, as it doesn't need to be replaced. Thus environmental impact does little to differentiate between the listed technologies. However, touch screen input actually is the best in this regard. As there will be a display anyway, with or without a touch screen, adding in a touch screen adds no more environmental impact to the project. Mice are probably the worst for the environment because they aren't very durable and must be replaced often.

3.2.3 Social Preference

To determine the social preference for each of the technologies, two surveys were conducted. First, we asked various students which technology out of touch screens, keyboards, trackballs, and mice they preferred. Out of a group of 20, the students unanimously voted for touch screens. However, they suggested considering using a Kinect as input. Thus we conducted another survey, asking to decide between using a touch screen and a Kinect. Out of a group of 10, 5 voted for the touch screen and 5 voted for the Kinect. These students were told the cost of each technology beforehand. Since they were split on the issue, we must consider other factors when deciding which to use.

Kiosks are commonly the first thing a person goes to when he or she enters a building. Kiosks are most often used only once. Thus the interface to the kiosk must be user-friendly and must be able to give out information efficiently. Without any detailed instructions, the user must be able to walk up to the screen and know exactly how to interact with it. In this section, we compare the usability of each technology.

Keyboards are very effective for home computers. However, in a kiosk scenario, they should only be used in particular cases. For a store kiosk, a keyboard is needed because a user needs to be able to type in product names or ID numbers. In the case of the new SUB, the user most likely won't need to type in a lot of information. They likely will have to select a location in a building or choose a resource statistic. Thus in this case keyboards are ineffective.

Mice and trackballs are used for pointing things out and selecting them. In the case of the display board at the new SUB, they would be perfectly suited for this task. As previously stated, the interface for the display board will likely have some sort of selection for location and/or resource usage. A pointing device like a mouse or trackball will be able to do this.

Touch screens would work extremely well in the new SUB atrium. They would be very user friendly. A user could walk up to a touch screen, touch the area of interest, and get a desired piece of information without any difficulty. With a keyboard, a command would have to be typed. With a trackball, the user would have to roll the ball first. With a touch screen, a simple touch reveals the information. Hence, in terms of usability, touch screens are a very good option.

The Kinect, being a new technology, will do extremely well in garnering student interest. As Kinects are rarely used in a kiosk setting, their uniqueness will be their greatest quality. Kinects are moderately easy to use for selecting information and as a plus, the user does not have to touch anything to use them. Thus the Kinect is a sanitary and socially plausible option.

3.3 Recommendations

In this section we covered the possible options for display board interactivity. A moderately expensive but usable option was the touch screen. The cheapest option was the trackball. Another popular option was the Kinect. However, we recommend going with a touch screen display system. Although the system is more expensive than most options, costing \$2000 over 10 years, the price is insignificant when compared to other aspects of the new SUB. Compared to the Kinect, it's less interesting, but the Kinect is too experimental for general use. We can't know what its interface will be or how usable it will end up. Thus the safer and cheaper bet is the touch screen.

4. A DISCUSSION OF DISPLAY BOARD PLACEMENT

4.1 Introduction to Current Display Placement Recommendations

The location of the display in the new SUB building is currently set to be in the atrium. From the atrium rendering provided by Chris Karu (Figure 1), there will be two levels on the main floor. One proposed location for the displays is the wall directly in front of the entrance on the first floor. Another option is the wall on the second floor. In the middle of the atrium, there is a room extending out from the third floor, hovering over the second. Since the room is in midair, the room is visible from both levels of the main floor. Thus, the walls surrounding this room can also be potential locations for the display boards. The entrance side of the wall and the ceiling of the atrium are windows designed to let through as much natural light as possible, so these two locations are not feasible options.

Another problem is the presentation of the display. Due to many issues, having a single large display board is not a viable option. As discussed previously, a better option is to use a number of smaller screens. All the small display boards can have different information, or the displays can be put together making one large screen. We consider both options.

To optimize viewability, various factors needed to be considered. Lighting and viewing angles are two such issues. Screen quality is different when under natural lighting during the day and under artificial light at night. To optimize viewability, each position in the atrium must be studied carefully. Another design consideration is gathering the most attention from people in the atrium. The display boards should be placed such that they are easily noticed. See Figure 1, the atrium rendering provided by Chris Karu:

Figure 1: An Artistic Rendering of the New SUB Atrium



4.2 Factors of Consideration

4.2.1 Presentation of Display

The displays will either be configured as many smaller screens making up one large display, or simply several smaller screens scattered throughout the atrium. Having a single gigantic display is not viable due to issues like cost, power, and spacing. As previously discussed (Table 1, Table 2, and Table 3), having the 46" TV is the most cost effective per square inch, in up front costs and power consumption.

4.2.2 Impact of Light Sources

The impact of light sources on the displays is one of the main factors being considered. Lighting changes throughout the day. Natural sunlight will be predominant during the day. Artificial light will be predominant during the night. Observing Figure 1, natural sunlight comes in from the window wall and the entire ceiling, meaning that the light will roughly be evenly distributed throughout the atrium during the day. Therefore most places inside the atrium should have the similar lighting conditions. Observing the windows on the sides, the direction of the sunlight will mainly be inward. Since the displays should block as little sunlight as possible, we can't place them on the side closest to the window. Other places in the atrium don't have this issue. Artificial lighting should be roughly evenly distributed as well. Since most artificial light will be on the top of the atrium, there will be no issues with glare at night. Except for near the windows, the lighting conditions should be fine almost everywhere inside the atrium. To maintain good image quality, as external lighting changes due to weather, artificial lighting should be carefully managed as to maximize viewability.

4.2.3 Viewability and Placement

To ensure optimal viewability, the displays must be in a location such that they can be seen anywhere in the atrium. Thus the displays can't be placed in the corner. People are not likely to walk by the corners of the atrium, and there is not enough room for many people to read the screens at once. Instead, the displays should be at the centre of the atrium where it is visible and many people can see it at once. Another factor to consider is the amount of people passing by. The main entrance of the atrium will have the most people walking by since everyone needs to go through entrance when entering or leaving. Therefore placing the displays near the entrance is essential. One possible location satisfying this requirement is somewhere on the walls at the centre of the atrium on the main floor. Furthermore, the displays should be placed in a comfortable viewing position. Places that require people to raise their head or move awkwardly should be avoided, like the walls surrounding the "floating" room at the centre of the atrium. If the displays are placed on the walls of this room, people would have to uncomfortably raise their heads in order to see it. Overall, in order to obtain the best viewability, the walls at the centre of the atrium on the main floor seem like the best options.

4.3 Recommendations

Overall, the best location for the display boards must satisfy the previously mentioned conditions. Placing the display boards on the wall on the first level of the main floor seems to be the best choice. There will be few glare issues at all times during the day since the location avoids the problem of people looking directly into light. The location certainly has the best viewability since there is a lot of room and the viewing angle is huge. In front of the entrance, many people will pass by, increasing the likelihood people will look at or interact with it. Therefore, considering all possible factors, we believe that placing the display boards on the wall on the first level of the main floor is the best option.

5. COMBINED CONCLUSIONS AND RECOMMENDATIONS

This report finds that a group of 46" LED televisions with touch screen kiosks would be the best option for a display board in the new SUB. The display is best suited for the first floor of the atrium on the wall underneath the stairs, but a group of display kiosks spread throughout the SUB is also possible. The 46" television size is the most cost and power efficient, and the LED display has the advantage in many areas, from lifespan to power consumption. They are also less harmful to the environment compared to LCD televisions. In terms of interactivity, we determined the best option to be a touch screen. It was very popular, and its costs were shown to be insignificant compared to other features of the SUB. Since a small screen was to be implemented in each individual kiosk in addition to the television screens, it was the obvious choice. Lastly, the wall of the first floor in the atrium was chosen for a variety of factors including light sources and viewability. There is a large amount of light in the atrium, and by placing the display on the main floor wall glare is minimized. This placement allows for the largest amount of people to view the display at any given time.

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