The Interaction of Color in the Context of Electronic Media:
Providing a New Platform for Exploratory Learning in the Additive Color Space

Thesis

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Abstract

This thesis research is constructed around leveraging applied, professional art practices coupled with emerging technologies to expand the educational experience in the Design classroom. By extending the classic theories of teaching Color Theory, rooted from the Bauhaus School, into a digital and interactive space, students are likely to have a better understanding and appreciation for the interaction of color in the digital space.

The experimentation of several interactive prototypes could potentially be used as options for enhancing different tasks in digitally manipulating color. A different concept for each prototype allows for a wider evaluation of the effectiveness of each prototype and create a more creative and exploratory experience for the final product. The difficulties that programming presents prohibit the completion of several conceptual prototypes. It would be interesting to examine the effectiveness of contracting the knowledge and abilities of one or two Computer Science students to assist in creating fully functional prototypes to strengthen the results of this research and to have the ability to create a final product for usability analysis and investor presentations.

This product will not only teach designers and emerging artists basic color theories in the digital space, but will allow the students to explore various color harmonies and color nomenclature based on the teacher’s lesson plan and allow a cognitive approach to manipulating the interaction of color in a digital setting.

Several prototypes were designed and developed containing various components centered around color theory. Each platform offers the student different ways to explore the interaction of color, with thorough explanations of
color interactions in the digital setting, such as color relationships, perception hue, and saturation and value. Lessons were reinforced by different interactive exercises throughout the system. Secondary research shows that various defined user experience elements need to be included during the design of the prototypes, such as accompanying feedback, providing the assistance that guides users in correctly manipulating the color on-screen. While one prototype may give the user complete control in each exercise, keeping track of each decision made throughout the experimental process, as well as offering tips to enhance or alter the outcome for different desired results.

Through an evolutionary process, the final prototype was more robust and addressed the results from each testing, while new concepts were introduced through iterative research. The first step was to design and develop a basic prototype that addressed the fundamentals of the in-class exercises. By first testing the usability of that prototype as well as assess student engagement and comprehension, the results were used to create an improved prototype the second time around. Additionally, by including new concepts in each successive iteration, the final prototype addressed needs of the student currently, while offering advancements that will create a better experience in the long run.

Using the application, students can interact with the interface and manipulate color with touch technology, a gesture based system such as the Microsoft Kinect or a web based point and click environment. By leveraging touch technology or interaction design in general, the student will participate in a richer interactive experience compared to one using a mouse and keyboard. The touch screen interaction mimics the actions akin to the analog experience of using traditional methods of cut paper and paint. Touch screen technology also opens the door to the possibilities of future implementation of a multi-touch experience and exposure to collaboration and co-creation in the classroom.
Dedication

For my parents.

Without your faith, support and tenacious love for Steely Dan, I would not be here. You will always be my inspiration to be the best I can be.
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I want to truly thank everyone who helped me through this process. First and foremost, my committee: Brian, Paul and Phil. You each contributed immensely to various aspects of this work in addition to inspiring me to succeed the entire way. In addition to my committee, many of the faculty at Ohio State’s Department of Design had a direct influence on my work. Thank you for constantly reminding me why I came to this University and why Design is such an incredible and rewarding field.

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Preface

1.1: Purpose and Scope

The main objective of this thesis is to propose an enhancement to the educational experience of color theory and communication course at the college level by introducing a digital interactive learning module designed to teach students about color interaction in the digital space.

The research has been constructed around leveraging applied, professional art practices coupled with emerging technologies to expand the educational experience in the Design classroom. By extending the classic theories of teaching Color Theory, rooted from the Bauhaus School, into a digital and interactive space, I hypothesize that students will have a better understanding and appreciation for the interaction of color in the digital space.

Several interactive prototypes have been developed and explored that could potentially be used as options for enhancing different tasks in digitally manipulating color. A different concept for each prototype fosters an evaluation of the effectiveness of each prototype and creates a more creative and exploratory experience for the final product. The difficulties that development presents prevents the absolute completion of several conceptual prototypes. Upon continuing this research, the knowledge and abilities of one or two Computer Science students would be necessary in creating fully functional prototypes to strengthen the results of the research and to have the ability to create a final product for usability analysis and assessment.

This product will not only teach designers and emerging artists basic color theories in the digital space, but will allow the students to explore various color
harmonies and color nomenclature based on the teacher’s lesson plan and allow a constructivist or cognitive approach rather than a reflective approach to manipulating the interaction of color in a digital setting.

Using the final two prototypes, students can interact with the interface and manipulate color with touch technology or a gestural based system, such as the Microsoft Kinect. By leveraging touch technology, the student will participate in a rich interactive experience compared to one using a mouse and keyboard. The touch screen interaction mimics the actions akin to the analog experience of using traditional methods of using cut paper and paint. Touch screen technology also opens the door to the possibilities of future implementation of a multi-touch experience and exposure to collaboration and co-creation in the classroom.

The hypothesis is that this module will enhance the learning experience and will make design students knowledgeable of how color interacts in the digital space. Exhibiting critical prototypes to participants, and conducting a task walkthrough along with a simple heuristic review will test this assumption.

The next steps of the research process will be to conduct another round of tests on a fully functioning, revised model that would be expanded to include additional exercises from the color theory course. After several successful tests and results from short-term implementations in the classroom, educational companies and investors interested in technology and interactive educational tools will be approached to acquire further funding and assistance to develop a fully functional application and potentially take the final prototype to market.
1.2: Audience

Over 300,000 digital design positions were held in 2009, expecting to grow 13% each year as the growing need for the industry rises (US Census Bureau, 2009). The target audience for this application would be an undergraduate student who is on track to apply to an undergraduate design program offering color theory as a foundational course. The target student would be interested in pursuing a career in the design field where digital applications are likely to be encountered such as web, animation, and motion graphics.

Design practitioners could also greatly benefit from this tool during daily design research and application. User testing and feedback for the tool could enhance the iterative research approach.

This research could be tested on future students in Color Theory and Communication 310 in the Department of Design at the Ohio State University. The reason for this test is to assess the ease of use of this interactive color theory module, designed to enhance the learning experience of color theory taught at the college level, as well as assisting design students in understanding the interaction of color in the digital setting.
Chapter 1: Introduction

1.1: Overview: Research Scope

Design practitioners today are faced with a multitude of options for altering and selecting color for their design solutions. Present-day graphic software incorporates options for altering color, designing in various color modes and the ability to view a design in differing monitor or output options. A designer can spend hours creating a beautifully detailed identity system for a client, complete with spec colors and a style guide for future usage of the brand they have designed. However, there is often a disconnect of the application of colors selected once the design enters the digital world. There seems to be a void in the available tools for designers to view the interaction of those colors on a screen.

While design students are exposed to the concept of color selection and the meaning of color in a traditional design curriculum, rarely is a student introduced to color application and color interaction in the digital setting. Through personal experience as a student and as an educator of the subject, it is apparent that the original format in which color is taught to design students remains in a physical context. Physical materials like colored paper and paint are used to teach the same lessons that were constructed by Josef Albers and Johannes Itten at the Bauhaus School of Design in Germany in the 1920s. Concepts such as color contrast and the illusion of transparency are still standard in today’s design courses, and are still being taught using the same materials despite the fact that the industry has changed considerably over nearly a century. While graphic design professionals may begin conceptualization with pen and pencil, the final deliverable is crafted on a computer almost immediately. The importance of color
accuracy the correct application of color on a computer is more important than ever.

Additionally, as competition among professionals increase in the professional world, the competition among design programs increases at an even more rapid rate. Simply obtaining a degree in design is not necessarily enough to secure employment as an entry-level designer. Designers are aware of the keen competition they face upon graduation and are being more selective upon choosing a program to attend for their undergraduate studies. As this selection process becomes more competitive, design programs need to expand their curriculum so that entry level designers have a larger set of applicable skills.

Research implies that of the seven elements of design; line, shape direction, size, texture, color, value; color is often the least emphasized element in a design curriculum. While the remaining six elements are constantly intertwined into the course exercises and lessons throughout one’s undergraduate design education, the exposure to color knowledge is contained within one course, if available, and is nearly always speaking to a print based output or deliverable. As media convergence expands, design curriculums need to broaden to include media output such as mobile, television and web platforms. Students are not only creating design for digital output, but are also creating design in a digital setting.

Current design curriculum teaches the concepts surrounding color in a physical arena. The mixing and interaction of paint and pigment differs greatly from that of the mixing and interaction of light or additive color. The education of key color concepts such as contrast and color interaction, are arguably different in subtractive and additive color models.

As technology continues to advance and design programs become increasingly competitive, there is an obvious void in color education of designers.
It is imperative that design programs who aim to stay ahead of the curve strive to offer students a knowledge foundation beyond simple drawing, typography and layout skills. It would seem that of the seven elements of design, there is a pattern of courses surrounding the education of color as being either cut or being combined into basic foundational courses. Many programs are cutting the color centric course entirely, due to budget cuts or lack of importance of the subject of color, and assuming students will develop a sense of color simply through experience or through cross disciplinary exposure.

Emerging technology can not only expand on the ability to teach the subject of color efficiently but also effectively and in line with today’s trend of digital output. Utilizing touch screen technology, gesture based systems, and digital environments utilizing real time feedback, students could quickly learn about the interaction of color, and experience the concepts of traditional color theory curriculum in a native format they are familiar with or will be using during the creation or delivery segment of the design phase.

1.2: Objective

This research coupled with statistics proving that over 97% of design graduates will be practicing their skills in the additive color space (US Census Bureau, 2009) begs the issue of whether students are able to execute the knowledge they gained during their foundational design (color) education. Based on interviews and communications with faculty at thirteen internationally recognized college design programs, only one out of thirteen reported offering a color course in which the topic of additive color mixing is approached, for one day out of a sixteen-week semester. One single day in which students are expected to absorb as much information as possible to aid in their professional practice upon graduation, which will take place on a computer, whether that digital device aids in creation or final outcome.
While traditional methods of learning about color mixing still remain viable, cut paper and paint are no longer the only tools available to teach students about color interaction and the importance of on-screen hue selection, contrast, and value. The interaction of on-screen colors on multimedia devices such as a mobile application or a time-based animation cannot be explained using paper and paint. Additionally, the spectrum that the additive (RGB) color space offers cannot be achieved using pigments or inks, such as those achieved in the subtractive color space. It is essential that students be able to conduct the standard color theory exercises in both color spaces, to further inform their practice of these theories, especially those centered around color interaction.

For example, at The University of Tennessee, the undergraduate Graphic Design program prohibits the use of the computer until the third consecutive year in the program, when students are formally accepted into the program. Once the first semester of the third year commences, they immediately begin executing their designs on a computer, and the majority of the courses take place in a computer lab. Unfortunately, at this time they have not received a formal introduction to using common graphic software or the extreme difference in color spaces they will face after spending at least two years using ink and pigment based processes to construct their designs.

Before beginning to formulate a design or concept behind the potential prototype, it is essential to being a thorough literary review of the subject matter. The basis for this thesis research lies within the synthesis of four intersecting points; color theory, interaction design, education and cognitive learning. The final solution proposed in this thesis can only exist when these four essential areas intersect. All of these areas of research need to be used concurrently because they each have properties that are contingent upon each other. It does not matter how beautiful the screens for the final interface are if these four areas are not being used simultaneously. Each one of the components deserves a
thorough examination. The following chapter will being to illuminate each subject matter in more depth.

Figure 1.1: Thesis Focus Venn Diagram
Chapter 2: Background

2.1 Color Theory

In the visual arts, color theory is a body of empirical instruction to color mixing and the visual impacts of specific color combinations. It teaches aspects of color perception, communication and how the meaning of color can affect the viewer’s interpretation of a work of art.

The color wheel is an artistry model that is formed by placing an arbitrary number of elementary colors based on a set of primaries in a perceptually linear progressive arrangement. The different color wheels arise from different ways of looking at color, whether it’s mixing light, mixing pigment, or working with perception. The number and choice of primaries vary among color wheels and artists use these primaries to obtain other colors. Red, Yellow and Blue (RYB) have been widely used as primaries in the Arts.

The 12-hue Johannes Itten Color Wheel is the most common model used to teach Color Theory [see Figure 1.1]. This color wheel forms contrasting elements to help visualize his theories of how shades and hues can come together. While there are other approaches to teaching color to visual art students, Itten’s wheel is most used because it’s primaries, red, yellow and blue have been widely used as primaries in the Arts, as traditionally artists have triumphed in using them to obtain a wealth of colors. Itten’s wheel is useful as a conceptual model for color since the relationships are easy to see, the system is easy to understand and has been principally used to teach color relationships since François D’Aguilon declared in 1613 that red, yellow and blue were primary colors and when mixed with black and white could produce all colors.
Additionally, from a perceptional point of view it makes perfect sense to use red, yellow and blue as primaries. The human eye is capable of pointing out a pure blue without traces of violet or green, a pure red without traces of violet or orange and a pure yellow without traces of green or orange. However, the human eye is unable to point out pure magenta or cyan.

The traditional 12-hue color wheel is based on the subtractive color system. Subtractive color systems start with light, presumably white light. Colored inks, paints, or filters between the viewer and the light source or reflective surface subtract wavelengths from the light, giving it color.

RYB (red-yellow-blue) make up the primary color triad in a traditional 12-hue subtractive color wheel [see Figure 1.2]. The secondary colors VOG (violet-orange-green) also make up another triad. Triads are formed by 3 equidistant colors on a particular color wheel. The remaining hues, the tertiary colors, are created by the combination of a primary and a secondary color.

Color theory was originally formulated under these terms, using three “primary” or “primitive” colors—red, yellow and blue (RYB), a historical set of colors used in subtractive color mixing. These colors were believed capable of
mixing all other colors. The principal idea that all colors can be produced from a set of primaries is essentially used in art and design education. Printers, dyers and painters, had long known this color mixing behavior but these trades preferred pure pigments to primary color mixtures, because the mixtures were too dull (unsaturated).

The RYB primary colors became the foundation of 18th century theories of color vision (the capacity of an organism or machine to distinguish objects based on the wavelengths (or frequencies) of the light they reflect, emit, or transmit), as the fundamental sensory qualities that are blended in the perception of all physical colors and equally in the physical mixture of pigments or dyes.

These theories were enhanced by 18th-century investigations of a variety of purely psychological color effects, in particular the contrast between “complementary” or opposing hues that are produced by color afterimages and in the contrasting shadows in colored light.

These ideas and many personal color observations were summarized in two founding documents in color theory: The Theory of Colours (1810) by the German poet and government minister Johann Wolfgang von Goethe, and The Law of Simultaneous Color Contrast (1839) by the French industrial chemist Michel Eugène Chevreul.

The idea that red, yellow and blue are the true subtractive primaries predates modern scientific color theory. Printer’s Magenta was invented in the 1890s for the CMYK printing process, when newspapers began to publish color comic strips [12]. Over time, designers and artists have demonstrated that magenta, yellow, and cyan is a better set of primary colors to use when mixing pigment [4]. For instance, mixing equal parts of magenta and yellow can produce red, and mixing cyan and magenta can produce blue.
The RGB color model is an additive color model in which red, green, and blue light is added together in various ways to reproduce a broad array of colors. Additive color mixing begins with black and ends with white; as more color is added, the result is lighter and tends to white. The name of the model comes from the initials of the three additive primary colors, red, green, and blue.

![Diagram of the CMYK and RGB Color Models](image)

**Figure 2.2: Diagram of the CMYK and RGB Color Models**
The main purpose of the RGB color model is for the sensing, representation, and display of images in electronic systems, such as televisions and computers, though it has also been used in conventional photography.

In established Art and Design programs, students are first introduced to the RGB color space when they begin learning computer software applications such as Adobe Photoshop. During this introduction, the topic of RGB color in contrast with CMYK color is discussed briefly, if it is even mentioned, leaving students uninformed and confused.

Available color systems are dependent on the medium with which a designer is working. When using ink or pigment to create color, a designer has a variety of paints to choose from, and mixed colors are achieved through the subtractive color method. When a designer is utilizing the computer to generate digital media, colors are achieved with the additive color method.

Students are taught the historical RYB color model in traditional Color theory curriculum, which typically takes place in the first or second year of study. Additionally, during the first and second year of visual communication design study, students are not conventionally taking courses requiring the use of a computer. For example, in my undergraduate experience at The University of Tennessee, the undergraduate Graphic Design program prohibited the use of the computer until the third consecutive year in the program, when students are formally accepted into the program. Once the first semester of the third year commences, they immediately begin executing their designs on a computer, and the majority of the courses take place in a computer lab. Unfortunately, at this time they have not received a formal introduction to using common graphic software or the extreme difference in color spaces they will face after spending at least two years using ink and pigment based processes to construct their designs.
The RYB colors that students have become accustomed to at this point in their education can not be converted into CMYK or RGB colors in a one step conversion, nor can CMYK or RGB colors be converted to RYB color values.

Two important and related transformations of the RGB color model are the HSV and HLS color spaces. Instead of making red, green, and blue the operative components of the space, these spaces describe colors in terms more natural to an artist or designer who regularly use computer software applications such as Adobe Photoshop:

- HSV—hue, saturation, value (also known as HSB, where “B” represents brightness)
- HLS—hue, lightness, saturation

The HSV/B and HLS spaces use models that assign values to these components in conical geometries [see Figure3.4].

Figure 2.3: Hue, Saturation and Value Model (HSV)
This thesis will explore new ideas using interactivity in new media, and the effects of applying those ideas when exploring the interaction of color in the RGB color space. Allowing students to manipulate RGB colors using the familiar HSV and HLS models found in common graphic software, the user (student) can control the following:

- How that color is created
- What color they see
- How the user will perceive that color in relationship to surrounding colors
- The interaction of the colors on screen to create either a harmonious or incongruous effect on screen

Contemporary color education must address the expanded range of media created by digital media and print management systems, which substantially expand the range of imaging systems and viewing contexts in which color can be
used. These applications are areas of intensive research, much of it proprietary; traditional fine art and design color theory curriculum does not include these complex new opportunities. The advantages of the real-time feedback and leveraging the dynamic RGB color space will provide a multitude of opportunities that can enhance the manner in which students can explore color in the digital space and build a foundation for manipulating spatial relationships between colors utilizing the additive color systems.

Results obtained when mixing additive colors are often counterintuitive for people accustomed to the more everyday subtractive color system of pigments, dyes, inks and other substances which present color to the eye by reflection rather than emission. For example, in subtractive color systems green is a combination of yellow and blue, in additive color, red + green = yellow and no simple combination will yield green. Additive color is a result of the way the eye detects color, and is not a property of light. There is a vast difference between yellow light, with a wavelength of approximately 580 nanometers, and a mixture of red and green light (Briggs, 2007). However, both stimulate our eyes in a similar manner, so we do not detect that difference.

2.2 The Interaction of Color

Color interaction is a perceptual effect that influences how color combinations appear to an observer. Two main categories are color induction and color assimilation, the former when two colors become more different looking, and the latter when two colors become more similar looking.
Figure 2.5: Color Induction

Color induction (chromatic induction, hue induction) refers to the change of hue when colors are perceived in the context of other colors. Depending on the color of the surrounding square the central neutral (gray) square gets a slight tint in the direction of the complementary color.

Figure 2.6: Color Assimilation

Color assimilation (Von Bezold spreading effect or Bezold-Brücke effect) is the opposite of Color Contrast: Colors take on the hue of the surrounding color, whereas color contrasts move it into the direction of the Complementary Color. Color assimilation makes the red-orange (left) and green (right) assimilate their neighboring colors.

In this survey of concepts and research, the focus is on fundamental issues and definitions regarding these effects. The emphasis is on the education of modern digital design students and relevant applications of different technologies. Historical perspectives are investigated and considered. Different
color appearance models and how they take color interaction into consideration are critical, in addition to applicable color adjustments each color model contributes to student comprehension of color interaction in the digital and physical space. Modern visual perceptual theories, and the place of these effects in a broader perceptual theory should be considered in an attempt to update contemporary color theory.

The importance of color and color interaction in different educational and professional applications needs to be explored with a set of guidelines. Advantages and disadvantages that may result from using the guidelines will be addressed. An additional goal for this research will be a series of suggestions for the advancement of the future of color theory and interaction for competitive Design programs offering courses for interaction designers.

There are three major classes of the interaction of color (on-screen): simultaneous contrast, successive contrast, and reverse contrast (or assimilation).

Simultaneous contrast may take place when one area of color is surrounded by another area of a different color. In general, contrast enhances the difference in brightness and/or color between the interacting areas. Contrast effects are mutual, but if the surround area is larger and more intense than the area it encloses, then the contrast is correspondingly out of balance, any may appear to be exerted in one direction only.
Successive contrast implies first one color is viewed and then another. This may be achieved either by fixing the eye steadily on one color and then quickly replacing that color with another, or by shifting fixation from one color to another.

Reverse contrast (sometimes called the assimilation of color or the spreading effect) takes place when the lightness of white or the darkness of black may seem to spread into neighboring regions. Similarly, colors may appear to spread into or become assimilated into neighboring areas. All such effects tend to make neighboring areas appear more alike, rather than to enhance their differences as in the more familiar simultaneous contrast, hence the term reverse contrast.
Figure 2.9: Reversed Contrast

*Gestalt theory can be used to explain the illusory contours in the Kanizsa Square. A floating gray box, which does not exist, is seen. The brain has a need to see familiar simple objects and has a tendency to create a “whole” image from individual elements.*

*Note that in the interaction of color in each example the constituent colors retain much of their own identity even though they may be altered somewhat by contrast.*

2.3 Interaction and Learning

Interactive learning describes a method of acquiring information through hands on, interactive means. The opposite of interactive learning is passive learning, which is merely observing a learning process or just listening to information. Interactive learning is a common method employed in schools today and often involves the use of computers and other tangible equipment.
There are two major approaches to using interactive learning systems and programs in education. First, people can learn “from” interactive learning systems and programs, and second, they can learn “with” interactive learning tools. Learning “from” interactive learning systems is often referred to in terms such as computer-based instruction or integrated learning systems (ILS). Learning “with” interactive software programs, on the other hand, is referred to in terms such as cognitive tools and constructivist learning environments.

The foundation for the use of interactive learning systems as “cognitive tools” (the “with” approach) is “cognitive psychology.” Computer-based cognitive tools have been intentionally adapted or developed to function as intellectual partners to enable and facilitate critical thinking and higher order learning. In the cognitive tools approach, interactive tools are given directly to learners to use for representing and expressing what they know. Learners themselves function as designers, using software programs as tools for analyzing the world, accessing and interpreting information, organizing their personal knowledge, and representing what they know to others.

There is no universally accepted definition of interaction in Design, Technology or Education. A summary of the various interpretations of the term interaction might be a kind of action that occurs as two or more objects have an effect upon one another. A system where all aspects are related and interdependent, every action has a result.

Burdened by a history of failed technology-based innovations (e.g., programmed instruction, teaching machines, and computer-assisted instruction), the latest buzzwords for interactive learning (e.g., interactive multimedia, the Web, and virtual reality) attract both enthusiasm and serious skepticism. Ultimately, all learning is interactive in the sense that learners interact with content to process, tasks to accomplish, and/or problems to solve. However this thesis refers to a specific meaning of interactive learning as involving some sort of
technological mediation between a teacher/designer and a designer/learner. An interactive learning system requires a device or system allowing a flow of information between it and at least one human being (a learner), responding to the user’s input. The student developing basic literacy skills via a multimedia simulation, the high school senior experimenting with the reactions of elements in a beaker learning chemistry, and the three-year old learning colors and letters by playing with wooden building blocks are all engaged in interactive learning.

Educators are constantly searching for innovative ways to efficiently and effectively engage and advance student learning. The following diagram points out the most effective ways students retain learned knowledge, so it is no wonder academia looks towards creating new experiences that involve students learning through doing, which has an average rate of 75% learning retention, just below results obtained from students teaching others.

![Learning Through Doing Diagram](image_url)

**Figure 2.10: Learning Through Doing**
Research indicates that experiential practice results in the highest level of retention (short of teaching others).

*Source: National Training Laboratories. Bethel, Maine

Edgar Dale (1954), an early researcher in the field of visual learning and the father of the Cone of Experience, is credited for the original linkage between instructional theory and communications. Dale’s original model of the cone does not include any percentages, and is explicitly described by Dale as a visual aid about audio-visual materials. His cone device is a visual metaphor depicting learning experiences, from the concrete to the abstract. No specific type of learning carries more value than another in Dale’s model, however he does contend that as one’s experiences more toward the bottom of the cone, more of the senses are engaged (such as hearing, seeing, touching, smelling and tasting).

While Dale’s Cone of Experience lacks percentages of effectiveness of the various types of learning or evidence of research having been conducted in formulating the cone device, this thesis research is attracted to the concept of moving towards a learning experience that is more theoretical, abstract and begins to engage more of the senses through one’s own exploration. In my opinion, this is the ideal method to engage a learner by giving them the ability to generate their own knowledge, gaining meaning from the experience and their ideas.
Figure 2.11: Edgar Dale’s Original Cone of Experience:

The cone device is a visual metaphor of learning experiences, in which the various types of audio-visual materials are arranged in the order of increasing abstractness as one proceeds from direct experience. Exhibits are nearer to the pinnacle of the cone because they are more difficult than field trips but only because they provide a more abstract experience.

*an abstraction is not necessarily difficult. All words, whether used by children or adults are abstractions.
Chapter 3: Color Education in Design Programs

3.1: A Brief History of Color Education in Design and The Arts

Although color theory principles first appeared in the writings of Leone Battista Alberti (c.1435) and the notebooks of Leonardo Da Vinci (c.1490), a tradition of “color theory” began in the 18th century, initially within a partisan controversy around Isaac Newton’s theory of color (Opticks, 1704) and the nature of so-called primary colors.

Figure 3.1: The first, 1704, edition of Opticks.
Cover and diagram of the theorem that “The Light of the Sun consists of Rays differently Refrangible.” His arrangement of the prism and the resulting orientation of the solar spectrum -- violet above and red below -- became canonical and probably encouraged the terminology of “ultraviolet” and “infrared.”

A color circle, based on red, yellow and blue, is traditional in the field of art. Sir Isaac Newton developed the first circular diagram of colors in 1666. Since then scientists and artists have studied and designed numerous variations of this concept. Differences of opinion about the validity of one format over another continue to provoke debate.

* Source states any color circle/wheel which presents a logically arranged sequence of pure hues has merit.
Figure 3.2: Sir Isaac Newton and his diagram of colors, 1666.

Newton’s conceptual arrangement of colors around the circumference of a circle (right), which allowed the painters’ primaries (red, yellow, blue) to be arranged opposite their complementary colors (e.g. red opposite green), as a way of denoting that each complementary would enhance the other’s effect through optical contrast.

Figure 3.3: Newton’s diagram of the color prism behavior
For much of the 19th century artistic color theory either lagged behind scientific understanding or was augmented by science books written for the lay public, in particular Modern Chromatics (1879) by the American physicist Ogden Rood, and early color atlases developed by Albert Munsell (Munsell Book of Color, 1915) and Wilhelm Ostwald (Color Atlas, 1919).

Major advances were made in the early 20th century by artists teaching or associated with the German Bauhaus, in particular Wassily Kandinsky, Johannes Itten, Faber Birren and Josef Albers, whose writings mix speculation with an empirical or demonstration-based study of color design principles.

![Figure 3.4: The Munsell Color System](image)

![Figure 3.5: The Ostwald Color System](image)

The foundations of pre-20th-century color theory were built around “pure” or ideal colors, characterized by sensory experiences rather than attributes of the
physical world. This has led to a number of inaccuracies in traditional color
theory principles that are not always remedied in modern formulations.

The first problem with these foundations is that there has been a confusion
between the behavior of light mixtures, called additive color, and the behavior of
paint or ink or dye or pigment mixtures, called subtractive color. This problem
arises because the absorption of light by material substances follows different
rules from the perception of light by the eye.

The second problem results from the failure to describe the very important
effects of strong luminance (lightness) contrasts in the appearance of surface
colors (such as paints or inks) as opposed to light colors; “colors” such as browns
or ochres cannot appear in light mixtures. Thus, a strong lightness contrast
between a mid valued yellow paint and a surrounding bright white makes the
yellow appear to be green or brown, while a strong brightness contrast between a
rainbow and the surrounding sky makes the yellow in a rainbow appear to be a
fainter yellow or white.

Finally the third problem derives from the tendency to describe color
effects holistically or categorically, for example as a contrast between “yellow”
and “blue” conceived as generic colors, when most color effects are due to
contrasts on three relative attributes that define all colors; lightness, saturation
and hue.

3.2: Johannes Itten and the Bauhaus School of Design

In determining his new aspects for color, Johannes Itten created a 12-hue
color wheel that forms contrasting elements to help visualize his theories of how
shades and hues can come together. Not only did he show how colors could be
grouped based on their pigments, Itten was also interested in how they would
affect a person psychologically. He taught theories on this while at the Bauhaus.
This included religious, philosophic, and psychological associations recognized in specific colors.

![Figure 3.6: Johannes Itten’s 12-hue Color Wheel](image)

Color Theory pedagogy at the Bauhaus became more subjective and exploratory to an individual’s preferences and sensations. Part of the instruction was to have students develop their own palettes of subjective colors, which comprised a large range of choices. The question of “how” someone perceives color was explored with a constructivist approach.

One of the most recognized reference materials for color instruction is the color wheel that Itten produced at the Bauhaus. Not only did this influence future use of color through the 20th and into the 21st century, but the research and material produced during that time is the most prevalent color tool for interior designers, architects, artists and all other creative individuals today.

Another pivotal figure in color education, Joseph Albers’ work was ground-breaking, for its breadth as well as its focus. His work provided the
foundation which sparked many artists to further study. But the translation of his ideas into classroom assignments need to expand to include the principles of color theory that consider digital color spaces.

Figure 3.7: Albers’ Study for Homage to the Square

3.3: Examining Modern Trends in Color Education

In today’s classroom, students learn how people see color, how they mentally process it and how they interact with it in all aspects of their lives. Fine art and Design students are taught to apply color theory consciously, so their work impacts the viewer in premeditated ways.

A 12-hue color wheel is commonly used to teach color theory. Johannes Itten created this color wheel that forms contrasting elements to help visualize his theories of how shades and hues can come together.

The continued reliance by design students upon non-iconic art, by which a works syntactic qualities such as color are highlighted, would seem to necessitate color education. But lacking this foundation, students allured by color are apt to find themselves in a wasteland where initial studio experiments and
attempts to gain further insight into color through books provide little or no assurance of understanding and clarity.

Further difficulties arise for design students as the distinctions between art, physics, psychology, psychophysics, chemistry, and philosophy blur when investigating color. Available texts are sometimes contradictory, misleading, and infrequently incorrect.

* A recent best seller stated Seurat would juxtapose yellow and blue dots that would mix optically to a green brighter than any found in a tube of paint -- something completely impossible.

Colors formerly said to only be reproducible from three colors are now easily reproduced with four process colors (sometimes more).

- There is an ongoing debate over the true primary colors:
  - cyan, yellow, magenta for printing processes and transparent painting media
- red, yellow, blue for painting and other media that operate with opaque pigments
- red, green, and blue relating to our tri-chromatic retinal processing that forms the basis for inventions like color televisions
- yellow, blue, red, green, describing our post retinal coding of colors, called the *opponent process

* Discovered by attributes of perceptual oddities such as afterimages and contrast effects (all of which must appear confusing to art students who lack a foundation in color theory.)
In presenting this conflict between color experience and academic bias, this research intends to utilize interaction design, basic principles of instructional design and a constructive learning approach to create an effective and efficient color education experience. In this world where essentially every seen experience enters us through color channels and is interpreted by us as color information, it seems necessary to investigate why foundational color theory curriculum remains unchanged in art and design programs in this country.

A questioning of the reasons for unvarying color education begins by re-examining “Interaction of Color” (1963), a highly regarded work by Joseph Albers upon which students are provided as a handbook for investigating color. With a pack of color aid in hand (a set of around 300 silkscreened papers) students start on page one and diligently work their way through most of the book’s exercises. By the end of the semester, each have, like everyone else, studies that attempt to replicate the effects illustrated in the book.

Students later stand in front of their own work wondering what relevance simultaneous contrast could possibly have to their interface design or product design. The students recognize that one color appears to change a bit when surrounded by another color, but so what. The lesson may never translate to the digital world, where they spend the rest of their time studying design and in professional practice. Furthermore, this method teaches many design students that color is limited, apparently, to hard edge and optical configurations.

Today’s Design students have grown up familiar with digital media, and are quick to use digital tools in their study and practice. Likewise, the ease in which materials such as interference colors and fluorescents can be obtained certainly influences the range of pigments and effects designers can now use. Further the contradictions embedded in color semantics, problems with warm and cool colors are fruitless attempts at categorizing feelings by colors, or the
difficulties in naming colors certainly suggest possibilities for exploring relationships between color and language.

In light of such an abundance of new technologies and possible color experiences, competitive academic interest in color should be at an all time high. Yet, indications suggest decreasing lack of consideration for color in contemporary art and design education. Competitive design programs are revamping undergraduate foundations and eliminating color courses first. A number of past conferences at the College Art Association, the annual major conference for the United States and Canada, shows the ease with which leading art and design programs facing budget cuts chose to eliminate their color courses.

Color information can not be dismissed or lumped into general design overviews as though best learned through the process of gradual or unconscious assimilation of knowledge. Art schools will not discard drawing classes and begin to assume these skills will be picked up in design courses, why color? Contemporary design education must address the expanded range of media created by digital media and print management systems, which substantially expand the range of imaging systems and viewing contexts in which color can be used. These applications are areas of intensive research, much of it proprietary; artistic color theory has little to say about these complex new opportunities.
Chapter 4: Interactivity and Technology

4.1 Overview of Interaction Design

One of the key elements to a successful digital interactive prototype is interaction design, the discipline in which designers examine the interface between people and products or environments. It is the meeting point between design and new technology and it is applied to products design (McDermott, 2007). Also known as interface or human-computer interaction (HCI) design, it is a user-centered perspective of design and focuses on the convergence of physical and digital technologies. It also explores culture and society, especially the role of technology in people’s lives.

Although this field has roots in traditional design practice, it is now largely concerned with products and services that use information technology. Traditionally, the design of mechanical devices such as typewriters, bicycles and washing machines focused on functionality and aesthetics. In products using digital technologies, however, the connections between form, function and usability can be less obvious.

Interaction designers therefore use a multidisciplinary approach, drawing on theory as well as practice, to make communication and interaction with computer-based devices as transparent and user-friendly as possible. The aim is to create designs that will enhance ease of use and the exchange of information and so will be successful in the market place.

“Our interaction with technology should be designed according to human needs instead of the user being required to adapt to technology. Even so, technology may change quickly and people and their habits change slowly” (Norman 1988). Ease of use has been recognized as a key factor influencing user’s acceptance of new technologies, as in the Technology
Acceptance Model (TAM) framework (Davis 1989; Kaasinen 2005) and in the innovation diffusion framework (Rogers 1995).

4.2 User-Centered Design vs. Technology-Centered Design

In approaching the interactivity of the prototype, I took a user-centered design strategy as opposed to a technology-centered design strategy. It is beneficial to mold the interface around the capabilities and needs of the end user. This philosophy is not born primarily from a humanistic or selfless desire, but rather from a desire to obtain optimal functioning of the overall human-system relationship. Rather than displaying information that is centered around the sensors and technologies that produce it, a user-centered design integrates this information in ways that fits the goals, tasks and needs of the users. If the interactivity of the prototype meets the needs and desires of the user, the technology can fall into place.

There are disadvantages of systems designed and developed from a technology-centered perspective. Using this strategy, an engineer may develop systems needed to perform each function. A display is provided for each system so the user is informed during operation. As technology is improved by the engineer more displays are added. The user is now trying to keep up with the exponential growth of data created by this process. There is little attention paid to the information architecture, the user experience, or the ease of use.

From a cognitive perspective, people can only pay attention to a certain amount of information at once. As the display of data in these systems is centered around the technologies producing them, it is often scattered and not ideally suited to support human tasks. A considerable amount of additional work is required to find out what is needed and extra mental processing is required to calculate the information the operator really wants to know. This inevitably leads to higher than necessary workload and error.
The attempt to automate our way out of so-called human error has only led to more complexity, more cognitive load and catastrophic errors associated with losses of situation awareness.

The optimal strategy for this thesis research was an approach to user interface design and development that involves users throughout the design and development process. It not only focuses on understanding the users of a computer system under development but also requires an understanding of the tasks that users will perform with the system and of the environment (organizational, social, and physical) in which they will use the system.

Taking a user-centered design approach should optimize a prototype’s usability. User-centered design provides a means for better harnessing information technologies to support human work. As a result of user-centered design, the final prototype could greatly reduce errors and improve productivity without requiring significant technological capabilities. Along with user-centered design also comes improved user acceptance and satisfaction as an additional benefit, by removing much of the frustration common to today’s technologies.

4.3 The Benefits of Technology in the Design Classroom

Technology is ubiquitous, touching almost every part of our lives, our communities, our homes. Design professionals and students are especially inundated with technology in their creative environments. Yet most schools fall far behind when it comes to integrating technology into classroom learning (Edwards, 2000). Many reputable design programs are just beginning to explore the true capacity technology offers for teaching and learning. Properly used, technology can help students in all disciplines, not just design, acquire the skills
they need to survive in a complex, highly technological knowledge-based economy.

Integrating technology into design classroom instruction means more than teaching basic computer skills and graphic software programs in a separate computer class. Successful technology integration must happen across the curriculum in ways that research shows deepen and enhance the learning process. In particular, it must support four key components of learning: active engagement, participation in groups, frequent interaction and feedback, and connection to real-world experts. Effective technology integration is achieved when the use of technology is routine and transparent and when technology supports curricular goals.

This thesis proposes that technology-enabled project learning can enhance the effectiveness of classroom instruction, particularly in the domain of color theory. Learning through the traditional Bauhaus color exercises coupled with technology tools allows students to be intellectually challenged while providing them with a realistic snapshot of how color interacts and behaves in the digital setting. Through exercises translated into the digital spectrum, students acquire and refine their analysis and problem-solving skills as they work individually and in teams to find, process, and explore information they’ve discovered during a lecture or physical version of the same exercises.

New high-tech tools for visualizing and experimenting with color offer students ways to experiment and observe the interaction and behavior of color and to view results in graphic ways they are familiar with and that aid in understanding. And, as an added benefit, with technology tools and a project-learning approach, students are more likely to stay engaged and on task, reducing behavioral problems in the classroom, lack of focus and provide long-term memory absorption.
Technology has the ability to reshape the way design educators teach, offering effective ways to reach different types of learners and assess student understanding through multiple means. A well designed interactive teaching tool has the ability to enhance the relationship between teacher and student as well as relationships among design students from different disciplines. Encouraging communication from student to teacher and student to student opens up the possibility of a meaningful dialogue inside the classroom that can encourage creativity. Additionally, this form of communication can help take away some of the pressure students might feel by expressing their lack of understanding of a topic they would normally be taught through a passive lecture or reading exercise. When technology is effectively integrated into subject areas, teachers grow into roles of adviser, content expert, and coach. Technology helps make teaching and learning more meaningful and fun.
5.1 What is Instructional Design?

Instructional Design is the process by which instruction is improved through the analysis of learning needs and systematic development of learning materials. Instructional designers often use technology and multimedia as tools to enhance instruction. Instructional Design involves systematically applying a set of principles to achieve effective, efficient, and relevant instruction (Briggs, 1991).

The basic principles of instructional design can be applied to assure congruence of objectives, instruction, and evaluation. Additional benefits can be increased effectiveness, efficiency and relevance of the instructions. For example, in Mastery Learning environments it has been shown that most of the students, when time to learn is allowed to vary, can achieve mastery of all stated objectives. Efficiency may mean that learners achieve the desired level of performance more quickly. Mastery Learning is an instructional method that presumes all children can learn if they are provided with the appropriate learning conditions (Gusky, 1986). Specifically, mastery learning is a method whereby students are not advanced to a subsequent learning objective until they demonstrate proficiency with the current one. In general, mastery learning programs have been shown to lead to higher achievement in all students as compared to more traditional forms of teaching (Anderson, 2000; Gusky & Gates, 1986).

Instructional Design requires comparison of the final version of the instruction with an alternative or at a minimum with its original objectives. Any system must have an overall goal. The ultimate questions for an instructional design system is, “Does it work?” No matter how attractive it might look and be viewed by experts, it must meet the challenge of resulting in an acceptable level of performance by learners within its delivery constraints.
5.2 Characteristics and Role of Instructional Design in the Prototype

The following characteristics represent the heart of the Instructional Design process in this thesis research. These characteristics were omnipresent in an Instructional Design literature review. Industry standard states they should be present in all Instructional Design efforts (Di Vesta, 1988). They were vital factors when designing the instructional components of the prototype. The instructional module of each evolutionary iteration of the prototype was heavily scrutinized against these characteristics to ensure successful delivery of the educational content to the end user.

- Instructional Design assumes the goals and objectives of the instruction can be agreed upon and stated.

- Instructional outcomes must be directly measurable in a valid and reliable fashion.

- Instructional Design focuses on the learner rather than the teacher. The goal is changes in learner knowledge, skill, and attitude. The teacher is seen as only one instrument in achieve these ends. Sometimes, the teacher may not even need to be present during much of the times the learner is learning.

- There is much more to be learned about how to design instruction. Recognize there is much more research and development needed about the process and its underlying knowledge base.

Determining what constitutes “quality” is ultimately a question of values. As I developed the prototype, conversations invariably turned to underlying ideas about what good teaching constitutes, particularly at the college level. I came to see that these fundamental educational values are the foundations of good
practice in undergraduate education, and good practice in instructional design. I was further influenced by an overall pattern found in mission statements of the universities and design programs I researched during my curriculum study, and a personal commitment to creating a prototype serving global education purposes.

The values are listed below in order to make those underlying values explicit, and to make clear how carrying them forward into the prototype creation process guides the development of a quality learning experience. This statement on values in not intended to be rigid. Depending on the discipline, the specific course being taught, and an understanding of the educational process, the values may differ, to a greater or lesser extent. The goal is that this list serves to stimulate further and deeper discussion about educational values, as I strongly believe that this critical self-exploration is essential to our success as teachers and academics.

The prototype quality elements listed below have been designed to support the following educational and design values.

- *Transparency* – The instructor’s expectations for all aspects of the prototype are made clear and are easily accessible to the students (Littlewood, 1991).

- *Alignment* – Prototype exercises and objectives are internally consistent. In-class lectures and exercises are closely aligned to the learning objectives (Robers, 1998).

- *Universal Design* – The prototype is designed to support all learners. High-quality design is universal and inclusive, and avoids creating barriers for any individuals (Barak, 2009).
• **Responsibility** – The prototype is designed to encourage students to take control of their own learning, and to foster the value of lifelong learning (Middleton, 2005).

• **Co-presence** – The prototype is designed so that students do not feel alone in the digital environment. The prototype has been designed to encourage regular student-student and student-teacher interaction (Middleton, 2005).

• **Global Learning** – The prototype is designed to foster a personal mission to provide a global education to students.

• **Technology** – Technology use is appropriate to the learning objectives of the class, and does not act as a barrier to any students.

• **Adaptability** – The prototype is designed so that it will be easy to update, adjust for curricular changes, expand for additional or advanced color exercises and to respond to changes within the discipline (Middleton, 2005).

5.3 Overview of Learning Theories

“I believe that (the) educational process has two sides—one psychological and one sociological. . . Profound differences in theory are never gratuitous or invented. They grow out of conflicting elements in a genuine problem.” (Dewey, 1959).

There are three sets of learning theory generally used in educational circles, under the headings of learning theories fall: behaviorism, cognitivism, and constructivism. Behaviorism focuses only on the objectively observable
aspects of learning. Cognitive theories look beyond behavior to explain brain-based learning. And constructivism views learning as a process in which the learner actively constructs or builds new ideas or concepts.

All of them make important points, and while the prototype is centered around constructivism, the issue is the range of convenience and effects on the learner of each of the models. In other words what is the learning theory good for, or good at helping the learner achieve in their educational experience?

Identifying individual differences among learners can help improve understand and guide the learning process. People can be seen as possessing a number of intelligences beyond the linguistic and logical-mathematical abilities typically emphasized in schools. Learners also possess inter- and intrapersonal intelligences, musical, kinesthetic, and spatial abilities. It is also known that individual learners process information differently while they are reading or making mathematical calculations, for example. Learners have processing differences that influence how they handle visual, aural, or kinesthetic information. Information that is available through learning modalities or pathways that are better developed will be easier to understand and use.

5.4 Constructivist Learning Theory and its Effect

Constructivism is a revolution in educational psychology. Built on the work of Piaget and Bruner, constructivism emphasizes the importance of active involvement of learners in constructing knowledge for themselves. Constructivism emphasizes top-down processing: begin with complex problems and teach basic skills while solving these problems (Yount, 1996).
Constructivism as a paradigm or worldview proposes that learning is an active, constructive process. The learner is an information constructor. People actively construct or create their own subjective representations of objective reality. New information is linked to prior knowledge, thus mental representations are subjective (Crawford, 1996).

A reaction to instructional approaches such as behaviorism and programmed instruction, constructivism states that learning is an active, contextualized process of constructing knowledge rather than acquiring it (Wertsch, 1995). Knowledge is constructed based on personal experiences and hypotheses of the environment. Learners continuously test these hypotheses through social negotiation. Each person has a different interpretation and construction of knowledge process. The learner is not a blank slate but brings past experiences and artistic factors to a situation (Vygotsky, 1978).

A common misunderstanding regarding constructivism is that instructors should never tell students anything directly but, instead, should always allow them to construct knowledge for themselves (Driscoll, 1994). This is actually confusing a theory of pedagogy with a theory of knowing. Constructivism assumes that all knowledge is constructed from the learner’s previous knowledge, regardless of how one is taught. Thus, even listening to a lecture involves active attempts to construct new knowledge.

There are several theories surrounding the Constructivist Learning approach. The most interesting and appropriate research in student exploration of the interaction of color is centered around a method of inquiry-based instruction, discovery learning believes that it is best for learners to discover facts and relationships for themselves. It doesn’t matter how aesthetically pleasing the prototype screens are designed, if the student is not making the discovery of knowledge on their own, it seems the attempt to create a explorative solution for learning will be lost.
Chapter 6: Benefits and Opportunities

6.1: The Benefits of Implementing The Proposed Tool

In order to become a well-rounded Graphic Designer, there are a variety of skills that are essential to handling a clients or employers tasks proficiently. As competitive design education programs continue to adapt to today’s climate of media convergence, it is necessary to develop a more sharply focused curriculum in such fundamental elements as Color Theory. Color selection is a very important element in digital design because colors have an effect on your audience before they begin to read the content. When color is used incorrectly, it can compromise your design solution and confuse your target audience.

Nearly all private and public institutions, such as The Ohio State University, currently teach design students Color Theory and the communication of color using physical media, such as cut paper and acrylic paint. Translation of traditional methods from the physical space to the digital space has proven to be insufficient. Correct knowledge of color interaction on the computer is key to successful digital design, and cut paper and acrylic paint are not enough, and are no longer the only tools available. With emerging technology we have the to power to enhance the educational experience and give designers the tools to succeed. Today’s design graduates will be using a computer and jobseekers are expected to face keen competition; individuals with web and mobile application design and animation experience will have the best opportunities.

The interactive color theory modules are supplemental tools useful to the teacher communicating foundational color theories in the classroom. This software application/tool is an Interactive interface that not only helps teach designers and emerging artists basic color attributes in the digital space, but
allows students to create color schemes based on the teacher's lesson plan. This product supports the growth of cognitive skills as a new approach to manipulating color and understanding color relationships and schemes in a digital setting.

Using the applications, students can interact with the on-screen color and manipulate color with touch technology on a large scale Touch Screen. By leveraging touch technology, the student will participate in a richer interactive experience compared to one using a mouse and keyboard. The touch screen interaction mimics the actions educators have traditionally used within the analog experience of using traditional methods of using cut paper and paint. Touch screen technology also opens the door to the possibilities of future implementation of a multi-touch experience and exposure to collaboration and co-creation in the classroom.

6.2 Rationale and Areas for Improvement

This thesis will examine the effectiveness of various prototypes, which utilize interaction design and advanced technologies with color theory being the main component of experimentation. There are several arguments to support the purpose and benefit this research poses to the design industry as well as higher education.

First of all, students today need to be learning about color and the interaction of color on-screen. 7 out of 10 students graduating with a degree in Design will be salary or wage designer. Approximately 3 out of 10 designers are self-employed. Many did freelance work—full time or part time—in addition to holding a salaried job in design or in another occupation. In 2010, about 29 percent of graphic designers were self-employed due to the extremely competitive nature of the industry today. However nearly 100% of designers complete their design work on a computer (Bureau of Labor Statistics, 2012). Correct knowledge
of color interaction on the computer is key to successful design, and cut paper and acrylic paint are no longer the only tools available.

Secondly, many educators and researchers have criticized learning-style theories. Various researchers have attempted to provide ways in which learning style theory can take effect in the classroom. By experimenting with various learning theories within an interactive system the outcome of effectiveness will yield more meaningful results. The various results will allow me to create a wider rubric for interactive learning of color theory.

Thirdly, the final interactive prototypes will not only provide a useful educational tool for students, but educators and practitioners will also benefit from the ability to measure progress and assess feedback in order to improve performance and knowledge of color interaction.

Fourth of all, research states that interactive learning enhances comprehension and understanding (Middleton, 2005). Students are conditioned to retain material at different rates for varying purposes, paying attention to some portions of the lesson or exercise carefully and skimming others (Evers, 2004). Interactive learning modules will create experiences, which allow the students to do something or make something. If students are given the opportunity to be involved in the creation of something, this may give them a sense of involvement and ownership, which will give the learning more meaning. Students who may be struggling with the content are especially supported by the use of interactive guides and system feedback and support.

Lastly, 11 out of 13 institutions interviewed, such as The Ohio State University, currently teach design students Color Theory and the communication of color using physical media, such as cut paper and acrylic paint. The translation of traditional methods from the physical space to the digital space has proven to be insufficient. Correct knowledge of color interaction on the computer is a key
component to successful design practice. Cut paper and acrylic paint are no longer the only tools available and with emerging technology we have the power to enhance the educational experience and give design students a more in-depth cognizance of color interaction.
Chapter 7: Secondary Research

7.1: A Heuristic Review of Color: An Interactive Tutorial

Conducting a heuristic review allows a more in-depth look at the usability and functionality of such a large program, and the results will be beneficial as I begin developing a prototype for my current thesis direction of developing an interactive tool to teach color theory with a digital medium. Rather than conducting a task analysis, a heuristic review will take a look at the details of the design, ease of use, and whether or not the tasks are intuitive throughout the user experience. The following heuristics were examined during the review.

1. Consistency
2. Feedback
3. Visibility
4. Orientation
5. Error prevention
6. Affordances
7. Language
8. Design
9. Legibility
10. Task sequencing
Color: An Interactive Tutorial is an interactive CD-ROM that balances color theory and new media to explain how color is perceived, how it is used and misused, and how to effectively work in an increasingly full-color graphic communications environment. Color is at the center of graphic communications. Every stage of the process incorporates the proper use of color – from design, to production and printing. The interactive CD-ROM offers thorough explanations of all aspects of color: relationships, perception, hue, and saturation. Additionally, it features discussions reinforced by exercises throughout the CD-ROM’s system. The program’s workshop area allows users to apply the theory introduced. Originally the CD-ROM came with an accompanying Instructor’s Guide that provided an answer key, but this Instructor’s Guide is no longer available.

The program was released for educational purposes in 1999, which proposes that some of the design attributes are dated, and due to lack of technical abilities some of the functionality is under par for today’s standards of usability, universal functionality and design aesthetics.

However, this is considered one of the more prominent educational resources for teaching color theory. It offers valuable information to artists, designers, design students and design educators wanting to explore color theory in a digital setting. The main objectives of this program are pertinent to the education of color theory in digital space, and the is program inspiring despite its many flaws.

The heuristic review was centered around the color attributes sequence of the program. It focuses on teaching basic color vocabulary such as hue, value and intensity. The correct definitions of these words are as follows:

**Hue:** Color in the purest form, as determined by the dominant wavelength of the light.
**Value:** The lightness or darkness of the hue. Adding white to a hue produces a high-value color, called a tint. Adding black to a hue produces a low-value color, called a shade.

**Intensity:** Intensity refers to the brightness, or saturation, of a color. A color is at full intensity when not mixed with black or white - a pure hue.

The targeted user varies in age and educational background. The majority of users are going to be comfortable using a computer, and more than likely going to possess a higher than average interest in design or art in digital media.

The system effectively informs the user of the fundamentals of color theory and allows the user to exercise what they have learned through basic interactive activities.

On the contrary, overall the system is inconsistent, offers incorrect information at times, and the exercises are monotonous, lack motivation to the user and are void of interest. The navigation throughout the system is confusing, inconsistent, and ultimately leads to the possibility of the user quitting before completing their tasks.
After an initial analysis of the sequence, there are obvious defects in need of attention. In order to create a more effective interactive experience for the user, the navigation, legibility of instructional and informative text and various incorrect information need to be addressed immediately.
There are a few minor and critical defects obvious after a first impression. User immediately has to make a uniformed choice, and is unable to go back and change his/her decision once entering system. Once the system launches, a set of confusing instructions appears, preparing user for the ill-designed interface. Ironically a tool to teach color uses illegible color interactions when displaying larger amounts of information necessary to complete task. The system states it will present a demonstration of common functions, which never begins, and offers no way to navigate to the demonstration, so user immediately feels lost.

Certain buttons that appear clickable do not work, yet in other areas the same “button” works, and at times “button” will take you different places, which is a critical defect. An experienced user would restart the program and select the experienced user option. The main screen appears and they would be faced with more minor defects.

Furthermore, a new user is unsure where to begin and an experienced user is unable to begin sequence where they left off. There is no hierarchy in the navigation to prompt the user where to begin the interaction sequence. The button “Navigate” at the bottom is confusing, and serves no purpose, it merely reiterates the system navigation to the left.

Figure 7.2: Color - An Interactive Tutorial: Path Selection and Viewing Options
Color Attributes Sequence:

Figure 7.3: Color - An Interactive Tutorial: Color Vocabulary

Figure 7.4: Color - An Interactive Tutorial: Attributes Sequence Introduction
Figure 7.5: **Color - An Interactive Tutorial:** Learning about Hue

Figure 7.6: **Color - An Interactive Tutorial:** Learning about Value
After an analysis of the Color Attributes color sequence, it is clear that a simple, linear sequence keeps the user on task and ensures all information from the lesson is relayed to the user. The vocabulary is concise and uses simple language with proper visuals to enforce the lesson.

On the contrary, a user is unable to easily skip areas that are unimportant, or uninteresting. The main navigation is no longer available, design is poor, visuals are not stimulating, and colors represented are unnatural and vibrate to the user’s eye. This is due to technological restraints at the time. Details such as spelling and spacing create legibility issues.

Exercises promised to the user do not appear at the end of the lesson, which is a critical defect. A first time user would be unaware of how to begin color attribute exercises and would possibly quit.

**Let’s Explore Sequence:**
Figure 7.8: Color - An Interactive Tutorial: Isolating Value

Figure 7.9: Color - An Interactive Tutorial: Let’s Explore Sequence
The system menu and exit process is just as poorly designed. However, the main navigation is accessible through the “navigation” button. The same language is used throughout the system to attempt to establish consistency.

That being said, the navigation changes from screen to screen. There is no feedback at any point without actually selecting something, which is irreversible. Colors chosen are illegible and text is aliased, creating more legibility issues. “Exit” and “Quit” either execute the same task or operate differently depending on where the user is in the sequence.

The user is unable to save position in sequence, and is often confused on how to quit tasks. Many times buttons simply do not work and the user is forced to do a hard restart. Some buttons have an inferior “hit state” and the user assumes he is doing something wrong and quits due to frustration. These are just a few of the critical defects found during an initial analysis of this portion of the program.

In conclusion, this was just a glimpse into the possibilities of this tutorial. The main objectives of this program are pertinent to the education of color theory in digital space, and the program is inspiring despite many flaws. The following recommendations could positively affect the user experience and the educational
value of this program. The findings of this review will be used as a foundation during the design and development process of the initial prototypes of this thesis research. The following recommendations are likely to improve user experience and usability of this program.

- Implement a new navigation, with feedback and consistent placement
- Create new exercises for each lesson to motivate user to continue
- Allow experienced user total access, eliminating monotony
- Expand colors to adhere to current available color spectrum
- Pay attention to details such as spelling and correct language
- Give user more creative liberties in exercises and in workshop area
- Establish universal language for navigation as well as instructions
- Offer feedback, both in system navigation and during exercises
- Keep error prevention in mind, allowing user to go back with ease
- Make sure buttons in navigation and in exercises intuitively imply actions

7.2: A Usability Study: Competitive Analysis of Adobe Kuler and Color Schemer

The goal of this study was to analyze the usability of two different color theory websites based on three tasks. The two websites being analyzed are http://www.kuler.adobe.com and http://www.colorschemedesigner.com. The participants for this usability test are students at The Ohio State University who are learning about color theory. A total of nine participants were part of this usability study. Throughout three main tasks that were appointed to the students, some major flaws and weaknesses of the websites emerged, as well as some strengths.
Some of the weaknesses of the kuler.adobe.com website include the inconsistency of color hues once the user decides to change the base color, determining the base color, and the process in which to save and export a desired color theme. The main strength of this website was the ease of being able to change the value of the HEX color without much confusion. Some recommendations to the designers of this website include having an easier navigation from the main page to the “Create” page, having a way to adjust the values of one color while not having the system automatically change the rest of the colors, and having an easier way to save and export the color themes.

The main weakness of the colorschemedesinger.com website is a mislabeling of the HEX color as “RGB”. However, the users are able to quickly and efficiently export their desired color schemes onto a computer. Some of the recommendations to the designers include changing the mislabeled “RGB” label to say “HEX” as well as redesigning the input field for the HEX color to be an obvious link for the user to click on.

The three major tasks the participants were presented with include:

1. Creating a monochromatic color scheme based on the HEX color 0018FF.

2. Creating an analogous color scheme based on the HEX color FF0000.

3. Export your color theme into either an ACO (Adobe Color) or ASE (Adobe Swatch Exchange) file format.

These tasks were video taped and the users were asked to use the “think aloud” protocol, which allowed them to narrate the exact steps they were taking in order to achieve the aforementioned tasks. The following task analysis details the steps required to perform the three tasks, followed by the results of the usability study.
Task Sequence

1) Creating a monochromatic color scheme based on the HEX color 0018FF on the abobe.kuler.com website

The user first clicks on the “Create” link, which is located on the left menu of the home page (See Figure 7.11). This takes the user to a new page (See Figure 7.12). The user must now click on the word “Monochromatic” which appears under the “Select a Rule” menu. Now the user must locate the “HEX” input field below the “Base Color,” which is the color located on the middle of the page. The user must click inside the input field, type in the desired number, and hit “Enter” on his or her keyboard.

2) Creating a monochromatic color scheme based on the HEX color 0018FF on the colorschemedesigner.com website

The user must clock on the “mono” label or image at the top of the color wheel. The user must then click on the text on the bottom right of the main color wheel which is labeled “RGB” (See Figure 7.13). Then the user must type the desired number inside the new dialog box that opens up, and then click on the “OK” button.

3) Creating an analogous color scheme based on the HEX color FF0000 on the abode.kuler.com website

The user must now click on the word “Analogous” which appears under the “Select a Rule” menu. Now the user must locate the “HEX” input field below the “Base Color,” which is the color located on the middle of the page. The user must click inside the input field, type in the desired number, and hit “Enter” on his or her keyboard.
4) Creating an analogous color scheme based on the HEX color FF0000 on the colorschemedesigner.com website.

The user must click on the “analogical” label or image at the top of the color wheel. The user must then click on the text on the bottom right of the main color wheel which is labeled “RGB.” Then the user must type the desired number inside the new dialog box, which opens up, and then click on the “OK” button.

5) Exporting the color theme onto an ACO or ASE file type on the adobe.kuler.com website.

*Note: This task may only be done by a registered user of the website.*

The user must type a filename into the input box beside the color wheel, then click on the “save” button (See Figure 4). This saves the file and redirects the user to the main “theme” website. Then the user must click on the “download” button and save the file type onto the computer (See Figure 5).

6) Exporting the color theme into an ACO or ASE file type on the colorschemedesigner.com website.

The user must click on the “Export” menu at the top right of the page and then click on “ACO (Photoshop Palette).” The user must then click “Save” once the color theme is ready for exporting.
Figure 7.11: Adobe Kuler Website: Home Page
Figure 7.12: Adobe Kuler Website: Create Theme Screen
Figure 7.13: Color Scheme Designer Website: Home Page

Figure 7.14: Adobe Kuler Website: Input Field
Usability Analysis

Task #1 - Kuler.adobe.com:

All of the participants were able to perform this task by themselves. Most of the participants took between 1 – 2 minutes to complete the task.

Some of the most common issues include:

- Users didn’t know they had to change the “Base Color” in order to create a scheme.

- Users thought they could just write the HEX into the search bar in order to create the scheme.

- Users did not like the color scheme the system created for them, “this is not the color palette I would have created”.

- Users tried to alter the color scheme to personalize it, and ended up changing the hue every time.
• Users had no idea what the difference between the color modes were, and were blindly changing the colors.

In terms of efficiency, this process could be made simpler by letting the user create the scheme on the home page. Also, the “Base Color” could be put at the beginning of the row. This experience would be better if the system locked down the hue of other swatches so the user could easily and freely alter the value and saturation of the other swatches in the palette in order to make “their own” scheme.

Task # 1 - Colorschemedesigner.com:

For this task, only 1 participant was able to complete the task by himself. The rest of the users were given hints because they were lost and were starting to get frustrated with the system. Most of the participants took between 1 – 2 minutes to complete the task. The most common issue was that the user could not find the place to input the HEX color.

This process is efficient because the user gets what they want in just one step. The only problem is that the HEX field is mislabeled as “RGB” and the field in which to input the HEX value does not look like an input field.

Task # 2 - Kuler.adobe.com:

All of the participants were able to complete this task. For most of the participants, the task took between 0 – 30 seconds to complete. The users were not satisfied with not being able to change the color scheme to colors they wanted.

In terms of efficiency, this task is similar to the previous one. The users were frustrated about not being able to change colors independently, and some argued that the color scheme was not truly analogous. As for learnability, once
the participant got used to the sequence in the previous task, this new task was a lot easier.

Task # 2 - Colorschemedesigner.com:

All of the participants were able to complete this task. For most of the participants, the task took between 0 – 30 seconds to complete.

In terms of efficiency, this task is similar to the previous one. As for learnability, once the participant got used to the sequence in the previous task, this new task was a lot easier.

Task # 3 - Kuler.adobe.com:

Seven out of the nine participants were able to complete this task without help. For the two that were not able to complete the task, the users did not realize that a name had to be input into the “Title” field before being able to save. This was a common error for many participants, but the rest were able to figure out this step after a few tries with the system. Most of the participants took 2 minutes or longer to complete the task.

In terms of efficiency, participants were not able to save the file if they didn’t input a title, and the system gave them no feedback for this error. Then once they were redirected to the second page, users had a hard time finding the button to export the scheme.

Task # 3 - Colorschemedesigner.com:

All of the users were able to complete this task, most of them between 0 – 30 seconds. A few of the users were having trouble locating the “export” menu at the beginning, but eventually got to it.
Participants commented that this process was extremely easy and user-friendly. Overall, this task is extremely efficient.

**Adoption**

In terms of adoption for an academic setting, the theory behind these two websites is good, but there are some changes which must occur. First of all, neither sites are educational in their mission, so they are unlikely to be adopted in the classroom setting. After the test was over a few students who did not have time to participate were playing with both websites, commenting they were enjoying playing with the colors online. Therefore, students are genuinely interested in the concept. It should be noted that both of these sites were introduced to a color course during a previous quarter for exploration purposes and some students actually used it for their projects.

6.3: A Curriculum Study

Using the feedback from the competitive analysis and literature review, an initial prototype began to take shape. In addition to examining current interactive tools for color, and reading literature to aid in creation, it was also imperative to gather a general inventory of current color theory rubric in art and design programs. While The Ohio State University has a design centric undergraduate program, it is beneficial to look at a wide variety of programs catering to different types of artists and designers who will ultimately be working with color on a computer in their professional practice.

After interviewing educational professionals employed at thirteen different four year universities and researching each programs curriculum, I was able to construct an inventory of exercises, concepts and objectives for each program. By examining the inventory, looking for patterns and voids, I narrowed it down to the essential components I needed to include in the preliminary prototype.
It is essential to point out that out of thirteen universities, the program at Kent State University in Kent, Ohio is the only program with dedicated exercises surrounding additive color. Additionally, Anne Marie LeBlanc, the director of the School of Visual Communication Design at Kent State stated that out of the sixteen week semester, they typically dedicate one day to additive color exercises. While other universities, such as the University of Cincinnati and the University of Tennessee, among several others, declared that courses dedicated to the subject of color theory alone will be completely eliminated over the next 1-5 years due to budget cuts, a shift in program focus, or other undisclosed reasons. Making matters worse, some of the programs eliminating the color theory course affirmed they have not decided whether the topic of color will be even integrated into a separate design foundations course. The reasoning behind this seems to be that they assume design students will absorb everything they need to know about the subject through exposure or by default. I would strongly argue this assumption, as it has been proven that color knowledge is key to successful design practice.

However, there is a strong pattern among the course objectives, concepts and exercises that all thirteen programs submitted. It is clear that The Ohio State University if following a common formula being used by nearly all other school investigated. It seems the course curriculum was loosely based on the emphasis of design within the program, and what kind of design was in the foreground of the program. There seems to be two basic types of color theory courses, one that focuses on teaching students about the meaning of color and how to use color as a communication tool, and programs that teach students about color selection, and how to create harmonious or discordant color palettes. Either way, as stated before, 12 out of 13 of the programs contacted and researched are teaching these concepts to students using subtractive color and physical media to execute the in-class exercises and assignments.
It is crucial for these students to be exposed to color in a digital setting during their design education. Design is a professional skill, meaning that upon being hired, they are expected to be prepared across many facets. Designers should be ready to enter the industry upon graduation without additional education or skill preparation. The application of color should not be overlooked or discarded as one of the elements of design that students gain a complete understanding about during their undergraduate education. It is just as essential to achieving a successful result as drawing, layout, typography or imagery in their professional arena.

6.4: A Design and Interaction Survey

My initial approach was to create a design based on the knowledge I gained from being around the students at the Ohio State University. The NUS (National University of Singapore) is an industrial design centric program, and the curriculum currently does not include any sort of color foundations. Before diving into a hands-on color workshop, I decided to engage the students in small group discussions centered on the following topics:

- Cooperative Learning
- Just-In-Time Learning
- Design Research
- Memory Recall
- Positive Past Learning Experiences
- Negative Past Learning Experiences
- The Use of Interactivity in Design Classrooms
- What makes an interactive experience “Cool”?
In addition to small discussions, I created a small survey to gather information from the students who were hard to reach or unavailable. Overall, design students are driven to explore visual aids in seeking inspiration in the creative steps of the design process. Looking at blogs, or pictures, or examples online help guide their research and inspire creativity or innovation.

Additionally, getting accurate information is a key component of their creative process. They acknowledge the fact that not all beautiful designs function as they should. While they may refer to popular design blogs or website such as www.informationisbeautiful.net or aiga.org, they recognize that a beautiful design does not always mean a beautiful experience. During small group discussions several students commented that as a design student in a very competitive field in their country, they hope to themselves stand out from the competition by being the type of designer who can look at the bigger picture. In Singapore the number of graduating design students able to secure a position without moving abroad is very low, they realize that they need to be a well-rounded designer, with the ability to balance form and function with total harmony.

When asked how they approach new information in class, 37% of the students prefer to take notes, a popular method we have been taught since the beginning of our education. However, after taking notes, guided hands-on learning was a close second at 32%, with 18% preferring non-guided hands-on learning following right behind.

In response to the question, “What is the coolest website or application you use? Why?”, students in general are drawn to programs that offer customization and inspiration. Anything that allows them to customize everything down to color and typography gets their attention and keeps it longer.
Overall, many students expressed being drawn to interactive learning as well as programs or website that offered gentle tips or nearly invisible interfaces. They want to focus on the content or personal experience they are trying to achieve by using the tool, not the actual aesthetics of the tool itself, which I found very interesting coming from industrial design students.

These group discussions as well as surveys nearly contradicted my initial approach to the interface design of the first prototype. They not only forced me to simplify the look and feel of the interface of the exercises for the workshops I was going to conduct while in Singapore, but I also kept the interface for the final prototype very minimal based on this experience.
Chapter 8: Primary Research

8.1 Overview of The Evolution of the Prototype

The first step in generating these prototypes required compiling the results of current design program approaches to the subject of color. Highlighting repetitive themes and curricular objectives identified widespread areas of concern within the discipline.

Next, I mapped out prevalent content being taught and identified the most important lessons taught in color theory and how they translated to the digital space. It was critical to create a scaffolding of the inventory of exercises to determine which exercises required a formal educational background in the foundations of color theory of design and which exercises involve little experience with the subject matter. Below is a list of the universal concepts found in design programs offering course specifically about color theory or courses the contained elements of instruction based around color theory.

- Color Wheel
- Bias Color Wheel
- Additive and Subtractive Color Mixing
- Properties of Color
- Hue
- Value
- Intensity/Saturation
- Chromatic Grays
- Visual Color Mixing
- Successive/Simultaneous Contrast
- Color as Emphasis
- Color as Balance
- Harmony/Disharmony
- Color Schemes
  - Monochromatic
• Triad
• Complement
• Split Complement
• Double Complement
• Tetrads
• Analogous
• Expressive Use of Color
  • Emotional Color
  • Color Symbolism
  • Arbitrary Color

There are four prototypes that will be reviewed and displayed in this chapter. The final prototype is the result of thorough testing, iterative research and evolutionary design. The properties of each prototype should be considered in comparison to the previous version, in addition to the acknowledgement that certain features or elements have been introduced or taken away based on testing results or discoveries through literature review.

*Touch Screen Prototype*

The initial prototype is a result of preliminary heuristic reviews and usability tests of the combination of competitive interactive tools and comparative color manipulating tools. By examining current design trends and maintaining an easy to use learning structure, the design and usability of the first prototype tested well, but the instructional design and learning objectives needed solidification to create a more comprehensible application.
The initial prototype tested well, with students claiming the application was “fun an easy to use” and “easier and faster than working with paint”, however it addressed a more specific type of student, one who had been exposed to the foundations of color theory before beginning the exercises. This streamlined iteration is stripped of embellishing aesthetics, and focuses on functionality, student engagement and whether or not students who have never been introduced to the material understood how to complete the exercises and the reasoning behind them.
Large Scale Touch Screen

The final prototype was actually broken into two separate concepts. This prototype stayed in line with all previous iterations, using both positive and negative feedback from several rounds of testing in Singapore to provide a platform for a stronger application. However, an additional void became apparent during the creation and assessment of each prototype, which prompted me to create two final prototypes. This final prototype is centered around a large
scale touch screen environment, and the student typically interacting with the application alone.

**Figure 8.5: Touch/Gesture Prototype- Alter Saturation Screen**

**Figure 8.6: Touch/Gesture Prototype- Alter Value Screen**

*Gesture Based Additive Mixing Game*

While the previous application provided an effective platform for the digital translation of traditional color theory exercises, it was vital to explore additive color and how students understood its difference from subtractive color, and the interaction and mixing of additive colors on a very basic level. The fact that yellow is created by mixing red and green was foreign to most students, so this prototype’s aim is to visually represent that information to the students in a
fun, interactive and competitive environment, using a gestural based input device such as the Microsoft Kinect.

8.7: Gesture Based Game: Additive Color Mixing

Testing Goals

The purpose for this test was to assess the ease of use of this interactive color theory module, designed to enhance the learning experience of color theory taught at the college level, as well as assisting design students in understanding the interaction of color in the digital setting. It was my hypothesis that this module would enhance the learning experience and will make design students knowledgeable of how color interacts in the digital space. Exhibiting seven critical screens to four participants, and conducting a task walkthrough along with a simple heuristic review tested this assumption.
Introduction of Application and Interface

What I propose is adding a supplemental tool to the design foundations classroom, specifically in the courses teaching students about the importance of color. This Interactive interface will not only teach designers and emerging artists basic color attributes in the digital space, but will also allow the students to create color schemes based on the teacher’s lesson plan and allow a cognitive approach to manipulating the interaction of color in a digital setting.

Using the digital color theory application, students can interact with the interface and manipulate color with touch technology on a large scale HP Touch smart screen with a screen resolution of 1920 x 1200 pixels. By leveraging touch technology, the student will participate in a richer interactive experience compared to one using a mouse and keyboard. The touch screen interaction mimics the actions akin to the analog experience of using traditional methods of using cut paper and paint. Touch screen technology also opens the door to the
possibilities of future implementation of a multi-touch experience and exposure to collaboration and co-creation in the classroom.

The target audience for this application would be an undergraduate student who is on track to apply to the undergraduate design program. Ideally they would be currently enrolled in color and communication 310 at The Ohio State University. The student is not an advanced user of creative software programs, but is excited about the possibilities of interface and web design. His goals are first to graduate with his BS in Design, and then to attain an entry-level position at a well respected mid-sized firm. He excels in all of his design courses and is motivated in learning the skills he needs to search for jobs in a fast growing and competitive industry.

The system contains five modules, offering the student five different ways to explore the theories of color accompanied by thorough explanations of color interactions in the digital setting, such as color relationships, perception hue, and saturation and value. Lessons reinforced by exercises throughout the system. System’s workshop area allows users to apply the theories introduced. Accompanying feedback provides assistance and allows user to correctly manipulate the color interaction, while giving user complete control in each exercise, remembering progress, as well as offering tips.

The application launches a template exactly like the ones students currently use in class with the traditional methods of cut paper. Students are able to freely manipulate the colors based on color mode preference (RGB, CMYK, LAB, HSV, etc), and how the colors are interacting on the computer screen. The interface controls are clearly labeled so there is no confusion as to what they doing. The interface is designed to allow the student to navigate easily between exercises and modules. If the student would like to experiment with a different theory of color or download their color scheme they can easily do so by the use if intuitive interface controls, The application will remember a student’s progress.
and they can easily return to the exercise if they navigate to a different area of the application.

Additionally, students are able to compare results to classmates and try the exercises again to get a better score. By touching the home button at anytime they can return to the main menu and explore a different area of the application. Overall, the experience gives design students exposure to color interactions in the digital setting and prepares them for a competitive job hunt, and makes them a well-rounded designer.

**Testing Goals**

The reason for this test is to assess the ease of use of this interactive color theory module, designed to enhance the learning experience of color theory taught at the college level, as well as assisting design students in understanding the interaction of color in the digital setting. It is my hypothesis that this module will enhance the learning experience and will make design students knowledgeable of how color interacts in the digital space. Exhibiting seven critical screens to four participants, and conducting a task walkthrough along with a simple heuristic review tested this assumption.

**Proposed Contribution**

In order to become a well-rounded Graphic Designer, there are a variety of skills that are essential to handling a clients or employers tasks proficiently. As competitive design education programs continue to adapt to today’s climate of media convergence, it is necessary to develop a more sharply focused curriculum in such fundamental elements as Color Theory.

Color selection is a very important element in digital design because colors have an effect on your audience before they begin to read the content. When color
is used incorrectly, it can compromise your design solution and confuse your target audience.

Most public institutions, such as The Ohio State University, currently teach design students Color Theory and the Interaction of color using physical media, such as cut paper and acrylic paint. Translation of traditional methods from the physical space to the digital space has proven to be insufficient. Correct knowledge of color interaction on the computer is key to successful digital design, and cut paper and acrylic paint are not enough, and are no longer the only tools available. With emerging technology we have the power to enhance the educational experience and give designers the tools to succeed. Today’s design graduates will be using a computer and job seekers are expected to face keen competition; individuals with web site design and animation experience will have the best opportunities. This speculation is based on the overwhelming number of job openings for web design, interaction design, animation and 3-D design that can be seen on coroflot.com, core77.com, aiga.org, caa.org (Dec. 5, 2011) or any other number of sources designers utilize when seeking employment. Typically these design positions list the various graphic software applications a candidate must be familiar with in order to be considered for the position. Referencing any type of graphic software indicates the position will be working on a computer.

The interactive color theory modules will serve as a supplemental tool useful to the teacher communicating foundational color theories in the classroom. The use of an interactive module will help teach designers and emerging artists’ basic color attributes in the digital space, and will also create experiences, which allow the students to do something or make something. If students are given the opportunity to be involved in the creation of something, this may give them a sense of involvement and ownership, which will give the learning more meaning. Students who may be struggling with the content are especially supported by the use of interactive guides and system feedback and
support. These prototypes support the growth of cognitive skills as a new approach to manipulating color and understanding color relationships and schemes in a digital setting.

*Preliminary prototype design no.1*

![Figure 8.9: Touch Screen Prototype: Module Selection](image)

*Figure 8.9: Touch Screen Prototype: Module Selection*
Figure 8.10: Touch Screen Prototype: Itten’s Contrasts Exercises Selection

Figure 8.11: Touch Screen Prototype: Simultaneous Exercise Selection
Figure 8.12: Touch Screen Prototype: *Simultaneous Contrast Color Exploration*

Figure 8.13: Touch Screen Prototype: *Color Scheme Viewing and Downloading*
Figure 8.14: Touch Screen Prototype: View Solution at Full Screen

Figure 8.15: Touch Screen Prototype: View Classroom Solutions Comparison
Figure 8.16: Touch Screen Prototype: Change Exercise Menu

Figure 8.17: Touch Screen Prototype: Transparency Color Exploration
Use Case Scenario

Jeffrey is a sophomore who is on track to apply to the undergraduate design program during the spring quarter. He is currently enrolled in Color and Communication 310 at The Ohio State University. Jeffrey is not an advanced user of creative software programs, but is excited about the possibilities of interface and web design. His goals are first to graduate with his BFA in design, and then to attain an entry-level position at a mid-sized design firm. He excels in all of his design courses and is motivated in learning the skills he needs to search for jobs in a fast growing and competitive industry.

The system contains 5 main components, offering the student 5 different ways to explore the theories of color, with thorough explanations of color interactions in the digital setting, such as color relationships, perception hue, and saturation and value. Lessons reinforced by exercises throughout the system. System’s workshop area allows users to apply the theories introduced. Accompanying feedback provides assistance and allows user to correctly manipulate the color interaction, while giving user complete control in each exercise, remembering progress, as well as offering tips.

Once Jeffrey has launched the application, he is presented with five choices. Today in class they discussed Johannes Itten’s seven contrasts of color. The teacher has instructed them to take some time on the touch screen to experiment with the concept of simultaneous contrast. Once he touches the experiment option, Jeffrey is faced with a series of options. Since the lesson was about Itten’s contrasts, he chooses this option. He is then faced with a few more options. He touches simultaneous contrast.
The application launches a template exactly like the one the students are using in class with the traditional methods of cut paper. Jeffrey is able to freely manipulate the colors based on his preference and how the colors are interacting on the computer screen. The interface controls are clearly labeled so there is no confusion as to what he is doing.

If Jeffrey would like to experiment with a different contrast of color or download his color scheme he can easily do so through the interface, the application will remember his progress and he can easily return to the exercise if he changes his mind. Jeffrey is also able to compare results to classmates and try the exercises again to get a different result.

Overall, the experience gives Jeffrey exposure to color interaction in the digital setting and contributes to a formal cognitive development of the knowledge of color interaction. The exercises he experiments with in the module can assist in refining the sensitivities to successful design solutions.

**Next Steps from Pilot Study**

- Label all ambiguous buttons, or ensure the button uses universal symbols to convey function.

- Research comparative educational applications and the presence of user accounts and purpose. Re-evaluate the purpose of this function.

- Design a more intuitive, seamless navigation to endure ease of use.

- Delete the 4 color modes that the participants did not understand or devise a way to offer instructions throughout site without compromising the simple design and navigational elements.
• Consider including basic instructions throughout system that could be hidden once the content was read or if user does not feel like he/she needs them.

• Design color exercises appropriate for additional lessons to allow for a richer usability test in the future.

**Next Steps for Prototype Development**

• Conduct a second usability test once the revisions from the pilot study have been made, reaching out to a wider audience for better results.

• Design each screen for prototype development, including administrative screens.

• Implement prototype in the autumn quarter Color & Communication 310 course at OSU.

• Perform a comparative study between the results of students experimenting with color in the digital space (using the interactive digital application) and the physical space (using traditional methods of cut paper and paint).

As I begin to develop the prototype for my interactive project, it is important to begin looking at comparative applications and to examine what is working and what is not working, both functionally and aesthetically. During the winter term of 2010, I was able to conduct usability evaluations on two prominent websites that are recognized as being superior online applications for experimenting with color, as well as doing a heuristic review on an interactive application with goals similar to my own.

After analyzing the results of these three critical tests, I was ready to begin
designing and developing the application. After reflecting on my research so far, at this point I felt the application should offer thorough explanations of color interactions in the digital setting, such as color relationships, perception, hue, and saturation, etc. Lessons should be reinforced by exercises throughout the system and the system’s workshop area will allow users to apply the theories introduced either through the system or in the classroom. Accompanying feedback provides assistance and allows user to correctly manipulate the color interaction, while giving user complete control in each exercise, remembering progress, as well as offering tips.

By leveraging touch technology, the student will participate in a rich interactive experience compared to one using a mouse and keyboard. The touch screen interaction mimics the actions akin to the analog experience of using traditional methods of using cut paper and paint. Touch screen technology also opens the door to the possibilities of future implementation of a multi-touch experience and enables exposure to collaboration and co-creation in the classroom.

Third of all, after designing an interface and getting positive feedback from my Rich Media Design 674 course, I was ready to being testing the prototype during this quarter in Design Seminar 787. Using the digital color theory application, students can interact with the interface and manipulate color with touch technology on a large scale HP Touch smart screen with a screen resolution of 1920 x 1200 pixels. Overall, the experience gives design students exposure to color interactions in the digital setting and prepares them for a competitive job hunt, and makes them a well-rounded designer.

Last of all, I have evaluated the results from my pilot usability test, which was very successful. I was able to expose three areas in need of improvement, the absence of critical labeling throughout the interface, four of six color mode
options available to the user that none of the participants understood, and the confusion among the participants of the purpose of the personal user account within the application. All together, the participants were overwhelmingly interested in the goals of the application, and seemed captivated by the interaction and design of the interface. Each participant went so far as to say they would not only like to be a part of any further test of the prototype, but fully supported my efforts and were hopeful of the possibilities of future design students having the application become part of their design curriculum.

8.2: An International Color Study: Design, Workshops and Feedback

During the Autumn term of 2010, I had the incredible opportunity to join Professor R. Brian Stone in Singapore as a visiting scholar at The National University of Singapore. I used this time to take a closer look at the content I plan to incorporate into my final thesis prototypes. I coordinated several workshops for the students to learn about the fundamental basics of color theory as well as some more advanced workshops that allowed them to manipulate color in a digital setting.

After reviewing the results from my Pilot Study in the spring quarter of 2010, I was in search of ways to improve the prototype interface in order to create a more effective and fun learning experience that was driven more by the student’s curiosity.

**Color Workshop Planning**

Based on the results from the survey and the discussion groups I held with the students, I began designing a simple interface to use in a small experimental workshop teaching students very basic fundamentals about color theory. The
workshops would be held in the School of Design and Environment’s computer labs, to ensure the students would have the correct software and be familiar with the computer operating systems.

The content for the workshops needed to be scaled back from the concepts that were represented in my Pilot Study from the spring quarter.

Additionally, the students were going to need more supplemental materials in order to complete the exercises since the majority of them have had no exposure to color theory in their education. The concepts incorporated into the workshops are as follows:

- Basic Color Wheel
- Properties: Hue, Saturation, Value
- Color Harmonies: Achromatic, Monochromatic, Triadic etc.
- Complementary Color
- Color Transparency
- Using Color to create Dimension

The interface wireframes for the Color Workshops went through several iterations, based on student feedback after each session. The final interface wireframes are found in the following pages. The students used Adobe Illustrator to open the templates and I monitored the different tools they chose to manipulate color and recorded the various ways they completed the exercises. 7-10 students participated in each workshop, allowing me to have plenty of one-on-one time with each student as they approached the various exercises.

Once the students were finished with the exercises, we discussed the various aspects of the workshop. Was it fun? Was it educational? Which concepts
were difficult? Which task was difficult because of the software or lack of tools? How would you have completed a task different if the tools had been different?

Preliminary Content Design

Figure 8.18: Color Workshop: Color Vocabulary (Color Wheel) Screen
Figure 8.19: Color Workshop: *Color Vocabulary (Properties) Screen*

Figure 8.20: Color Workshop: *Color Vocabulary (Harmony) Screen*
Figure 8.21: Color Workshop: Color Wheel Basics Exercise Screen
Figure 8.22: Color Workshop: Complementary Color Exercise Screen

Figure 8.23: Color Workshop: Color Harmony Exercise Screen
Figure 8.24: Color Workshop: Simultaneous Contrast Exercise Screen

Figure 8.25: Color Workshop: Color Transparency Exercise Screen
Color Workshop Results

The workshop sessions were extremely helpful. The results were overwhelming and will enable me to begin a few new prototypes with various learning theory approaches and more in-depth lessons in the following quarters. I need to consider the following results before beginning the design and needed development of any new prototypes.

- The students at this academic level are not comfortable with Adobe Illustrator or Photoshop
- Larger groups can get too chaotic to manage
- The Interactive sessions need to follow a more comprehensive lesson on color theory
- The interface needs more instructional assistance
• The prototype(s) need to take into account different levels of comprehension
• Several students requested a quiz-like element incorporated into the interface
• Nearly every student remarked the color wheel needs a “middle”
• Students do not understand the difference between Saturation and Value
• Students want to be able to see a much larger Color Wheel
• Adobe Illustrator tools really limit the full potential of the exercises
• Students are not able to alter the saturation of a hue using its complement

**Plans for the Future**

Based on the results of the color workshops conducted in addition to ongoing literary research, the next iteration of the study will be to create multiple experimental prototypes utilizing interactivity to engage students and enhance the learning experience.

The next steps will be experimenting with creating a working prototype in Adobe Flash and Abode Flash Catalyst, which allows rapid prototyping. Additionally, it may be interesting to explore other systems allowing a different interactive environment, such as a gesture based system similar to the Microsoft Kinect.

The overall goal is to experiment with creating interactive environments that allows students to interact with color in various ways as well as exploring color in a multi-dimensional manner. Whether the students are interacting with projected light, learning about the interaction of reflective color or any other number of exercises, it is important that they understand that the outcome of any color is contingent upon multiple properties. It will be interesting to see how each prototype succeeds, fails, or offers new ideas for teaching students about color.
8.3: Revisions and Additional Prototype Development

During the winter term of 2012, I conducted a comparison of the constructivist and cognitive learning theories using two different prototypes. Each prototype is a platform allowing students to gain an understanding of color mixing in the RGB color space. The overall goal provides the appropriate platform to allow student understanding of digital color interaction in order to assist them in their design education and ultimately professional design practices.

Although I am currently studying in a program that is centered around design, similar design courses are taught in many art programs, and my research proves that both art and design based programs lack courses that discuss the RGB color space and digital color interaction.

The color workshops I conducted in Singapore along with the work I did with the Genetics Literacy Project at OSU’s Advanced Computing Center of Art and Design, I decided to improve upon and expand the two prototypes I had already tested, pushing interactivity to engage students and enhance the learning experience as well as focusing on the understanding of color mixing and interaction in the additive color space.

During the spring of 2011 I experimented with creating a working prototype in Interactive Media Arts 741 with Adobe Flash and Abode Flash Catalyst, which allows rapid prototyping. I also utilized my time in Visual Performance and Installation Technologies 758, where I created a computer mediated performance and installation system, focusing on real-time video processing, 3D graphics, and environmental sensing. Each prototype took elements and results from the research conducted testing the initial prototypes, and carried those concepts into richer, more engaging platforms, not only focusing on real time feedback of user interactions, but the effect of harmonious
and incongruous color combinations and the interactions of those combinations on-screen.

Additionally, through my iterative research, I found that it was important for the student or designer to experiment with these concepts on a screen size similar to the end result or the device he or she would be working on. Experimenting with on-screen color interaction at a very large scale is entertaining to the student, but hinders the understanding of the concept if the student ultimately is designing for a 320 by 480 pixel iPhone screen.

My overall goal is to experiment with creating interactive environments that allows students to interact with color in various ways. Whether the students are interacting with projected light, learning about reflective color interacting or any other number of experiences. It will be interesting to see how each prototype succeeds, fails, or offers new ideas for teaching students about color interaction in a more innovative and exciting way.

Final Touch Screen Prototype:

Figure 8.27: Final Touch Screen Prototype: Introductory Screen
Figure 8.28: Final Touch Screen Prototype: Spin the Wheel Screen

Figure 8.29: Final Touch Screen Prototype: Select a Hue Screen

Figure 8.30: Final Touch Screen Prototype: Directly Adjust Hue (add yellow)
Figure 8.31: Final Touch Screen Prototype: Rotate Color Wheel

Figure 8.32: Final Touch Screen Prototype: Color Property Menu (neutral saturation)
Figure 8.33: Final Touch Screen Prototype: Directly Adjust Neutral Saturation

Figure 8.34: Final Touch Screen Prototype: Indirectly Adjust Complementary Saturation
Figure 8.35: Final Touch Screen Prototype: *Save Created Color*

Figure 8.36: Final Touch Screen Prototype: *Begin Exploration Again*
Final Gesture Based Color Mixing Game:

Figure 8.37: Final Gestural Prototype: *Main Screen for Individual Play*

Figure 8.38: Final Gestural Prototype: *Main Screen for Game Play*
Research Design and Methods:
During the final evaluative sessions, the student will be asked to demonstrate the following three learning objectives in a controlled environment.

- Adjust the saturation of a given hue using its complement.
- Create a split-complementary color scheme.
- Create a specific hue (Yellow) by mixing additive light.

Based on the results of testing previous models of these prototypes, I believe these revised prototypes, both focused on additive color mixing, will aid in enhancing student comprehension of digital color interaction in multimedia platforms.

Results

Usability Analysis of Final Touch Screen Prototype

While evaluating the learning assessment of the latest prototypes, quite a few students offered feedback pertaining to the usability aspects of the prototypes. In an attempt to constantly be looking for ways to improve the concept, it is essential these ideas not be ignored. In addition to exploring a suitable platform for learning about the interaction of color in the digital space, there is a constant aim to observe people using the product to discover errors and areas of improvement. This particular usability test involved measuring how well test subjects respond in four areas: efficiency, accuracy, recall, and emotional response. The results of this test can be compared to the results of the testing of prototype no.1 to indicate improvement, and offer suggestions for the next step.
Areas of feedback from usability testing:

- Performance -- How much time, and how many steps, are required for people to complete basic tasks? (For example, find something to buy, create a new account, and order the item.)

- Accuracy -- How many mistakes did people make? (And were they fatal or recoverable with the right information?)

- Recall -- How much does the person remember afterwards or after periods of non-use?

- Stickiness -- How much time he/she spends

- Emotional response -- How does the person feel about the tasks completed? Is the person confident, stressed? Would the user recommend this system to a friend?

Positive Feedback:

Students overwhelmingly found the minimalistic approach to the interface design positive, allowing them to focus on the exercise and the interaction of the colors on screen.

Negative Feedback:

80% of the students commented on the lack of labels being a possible issue when using the application, even after the second and third usage. Each function needs to be clearly labeled, and demonstrate its functionality and purpose for each activity. If the function is not necessary in order for the student to complete the task, it should not appear on screen to avoid any confusion. Additionally, the four different ways to alter the colors are labeled with just the first letter of the
property a user can adjust; hue, saturation one, saturation two, and value. Using
the first letter is not enough information for some students, especially students
who are enrolled in the color theory course as a design minor or as an elective. It
should be taken into account that students from other disciplines will be expected
to use the application in the course and will need additional assistance and
instructions to participate.

The central circular piece does not have the same affordance as the tabs,
which glow in order to demonstrate their ability to be interacted with.

Despite the fact that students are able to adjust the properties of the colors on
screen by interacting with the application in two areas; the property panels on the
left hand side and the large circle in the center of the screen; there was confusion
where to begin the exercise. The mapping between the two devices was not as
clear as originally expected.

Suggestions for the next version:

The lesson preceding this exercise needs to include a brief introductory
lecture combined with a demonstration or a video explaining the various
exercises available within the application and the function of each tab.

There were varied results regarding the minimalistic 4-point color wheel. While
many students liked the unobtrusive interface, others felt differently. Some of the
suggestions received regarding the color wheel were:

- The ability to see a larger color wheel
- Making the 4 circles larger
- Adding circles as the user rotates the color wheel
- Including an animation as the user rotates the wheel to showcase what is
  happening behind the scenes
9.1 Project Summary and Objectives

The goal of this project was to create a prototype that could potentially be used as a method for enhancing different tasks in experimenting with additive color in a digital setting. Overall, I had observed that past and current offerings in the space tend to neglect user needs, provide inaccurate information and fail to allow the user to understand why colors interact differently with various colors based on their properties. By taking advantage of emerging technologies and a user centered approach, I hypothesized that a solution could be developed for the digital space.

To verify this hypothesis, I developed a research plan with the goal of getting useful data and implementing a new design. To begin, I did an analysis of the existing landscape. During this early investigation, I evaluated the design of color manipulation tools, educational tools and instructional aids that made a successful transition to a digital format. Additionally I did a thorough examination of design programs and their approach to color education. I interviewed instructors at thirteen international universities in order to accurately choose the best exercises to incorporate for the first iteration of this prototype. All of the information I gathered helped inform my design of a new solution.

With students in mind, I developed a set of surveys and interviews to better understand their needs and desires in the space. The information I gathered in those sessions allowed me to develop a prototype of an application on a large scale touch screen device. The prototype integrated needs that I heard specifically from student users as well as best practices in interactive design tools,
which included a simplified color wheel, real-time feedback, intuitive controls and a thorough explanation of the difference between value and saturation.

After that investigation, I began the development of a prototype around the exercise addressing simultaneous contrast. Through a series of testing, evaluating, revising and introducing new content, a generative approach allowed me to create a more in depth solution. Additionally I made sure to test the prototype on students with a wide range of exposure to the content. This enabled me to focus on the translation of the material and gauge the level of student comprehension with the application independent of lecture or tutorial.

The prototype went through an iterative design process over the course of its creation. Each prototype was designed, developed and then tested for ease of use, student understanding and the level of student engagement. Using the feedback and results of each assessment, I created an improved prototype while introducing new concepts or material into each successive iteration. This evolutionary design process allowed me to constantly keep the student’s needs as my priority in addition to ensuring that I was utilizing the best design practices as well as using the best interactive platform that would lend itself to creating a hands-on, exploratory learning experience.

After evaluative testing on a total of four prototypes with undergraduate students at Ohio State University as well as the National University of Singapore, I determined that this solution is highly desirable based on judgements and from the overall reactions of the students. Students had thoughts about improving the application in many ways but collectively expressed interest in using it in their classes. While there is still work to be done in this area, it is a clear step in the right direction.
9.2 Color Theory Courses of The Future

Professional designers work on a computer. Even when the final output may be a printed deliverable, the creation process takes place in a digital realm. There is no doubt that great emphasis is placed on beautiful layout, typography, hierarchy, and other elements of design in order to communicate effectively through design. Color is one of those very important elements that can either support the delivery of that message, or prevent it from being understood by the viewer.

Something as basic as legibility can be hindered by the incorrect application of color, especially in the additive color space where a designer has the choice of over 4 billion colors, as opposed to a pack of color-aid containing a range of 314 matt-finished colors. The color-aid system consists of 34 vivid hues (saturated colors), 100 tints (clean, light colors), 47 shades (dark, deep colors), 114 pastels (-muted, or soft colors) and 17 grays from dark to light, plus black and white.

The limitations this prescribed box of colored pieces of paper places on the lessons in today's color theory course has only begun to be outlined in this thesis. By allowing students to experiment with the interaction of colors in a digital setting instead of using the color-aid or physical pigments opens students up to opportunities that will actually apply to their professional needs and practice while engaging them in a meaningful way. The original exercises from Johannes Itten and Josef Albers remain essential to the curriculum today, but these standard activities must be translated into a digital setting, where students are not only more comfortable, but where they will actually be applying the lessons learned in the classroom.

What is the point of a design education if a design student is not able to apply a theory they have learned in a meaningful way? How often will a
professional designer be consulting his or her box of color-aid papers in order to create a color palette or to select two harmonious colors that contrast but do not vibrate once placed in close proximity? The answer is simple, they won’t. They will be experimenting with the properties of each color on their computer.

Introducing a digital application into the color theory classroom is essential as we move forward in design and color education. Students of this generation are already questioning classroom methods of using colored paper and paint. They are already recreating the exercises on the computer to accommodate for their digital portfolios. I believe the adoption of this prototype would not only be welcomed with a smooth transition, but would increase the ability for students to comprehend the concepts behind the exercises, open up more classroom time for additional significant course work, reduce the cost of enrollment and eliminate the amount of wasted materials in a typical color theory classroom. Additionally, programs who are terminating the color theory course due to budget cuts or other reasons would be able to incorporate an in-depth examination of color theory due to the application’s efficient way of handling the exercises and allowing students to quickly and accurately complete the lessons. Many students commented that many of the physical exercises they currently are required to complete in a color theory course felt unnecessary and monotonous. They stated that they understood the concept after either the introductory lecture or first hands-on experimentation, and felt the proceeding exercises were pointless, and they wished they could have moved on in the subject matter. If the application were incorporated into the classroom as a supplement to the exercises, more material could be covered over the course of a semester or quarter, therefore giving students a much deeper and much needed understanding of color.
9.3 Suggestions for User Interface Development

Upon starting this research, I knew that the feedback portion of the interface would be critical to the overall success. Due to constraints of time, I chose to primarily focus on the translation of two prominent color exercises into the digital space. Because students are the users that will benefit the most from using an application like this, I focused on creating an engaging and effective tool first. I felt that if the tool was overall successful at helping student understanding of color theory and the interaction of color, we could later expand the application to include more complex exercises around color and possibly even graduate into design foundations courses as a whole.

In order to allow the student to explore color in a multi-dimensional approach, four various properties of color are able to be manipulated in the final touch screen prototype. By allowing the student to alter the hue, neutral saturation, complementary saturation, and value of a single hue at the same time, they begin to see that the final outcome of a single color on-screen as well as its impact on surrounding colors is multi-dimensional. This type of exploration is not achieved using pigment. When mixing paint, a student can only view the final outcome of color mixing one property at a time.

In addition to creating a multi-dimensional exploration of color, the final prototype allows for the user to make mistakes, and offers memory recall. If the students is attempting to create a desaturated violet and accidentally adds too much gray or yellow, the final touch screen prototype allows the student to not only go back step by step, but also allows them to counteract the effects using any number of other solutions. When using color-aid or paint, the mistake is irreversible. The students must start over when using paint, and when using color-aid they may have to choose a completely different color scheme based on the availability of the remaining selections of color-aid pieces. For example, when a student is using color-aid to complete an exercise, once they have used the pure
red hue, it is no longer available for exercises in the future. Subsequently, any other color that require pure red in order to complete a particular harmony, scheme or contrast is also eliminated. In reality, the students are limited to even less that the original 314 colors included in the box of color-aid. It should also be noted that the high cost of color-aid often compels students to obtain already used boxes of color-aid, which nearly always prevents them from creating persuasive harmonies of interactions of color.

Prototypes no. and no.4 address the need for an iterative exploration of color. The student is given real-time feedback, and completes the exercises rapidly and is given visual cues when they have been successful in their exploration, or when the interaction of colors on-screen in front of them is not effective in the exercises at hand. By allowing students to quickly and efficiently understand the concepts behind each exercise, the class is able to intelligently move on to new content quicker, allowing room for more in depth discovery of more advanced learning objectives.

After my final evaluative sessions, it became very clear that the instructional component of the application is more important than I originally assumed. During the final evaluation sessions students who had demonstrated a firm grasp of the content before beginning the session still needed various prompts or assistance in order to truly understand exactly what was happening on screen with the interaction of the colors and why the interaction was harmonious or incongruous. When students complete the exercise in the classroom using colored paper, they expressed it felt more open ended, with a multitude of possibilities, and no correct final outcome. While that abstract outcome still applies to the digital exercise, students felt the need to repeatedly gain confirmation from me that their choices were correct and they requested permission to move on in the session rather than taking a more experiential approach the activities as I had hoped.
It would be interesting to investigate the benefits of including an instructor portion of the interface, offering students tips to improve their work through the exercises. Measures could be taken to evaluate the direct connection between student need and instructor feedback. Instructors need to be alerted when a student is creating a non-existing or low contrast on-screen interaction of colors when the learning objective is to explore the effects of high contrast interactions. Additionally, the application should provide rewards and the ability to advance and get progressively more challenging or engaging. With better understanding in this area, an interface can be constructed that allows them to work efficiently and in turn positively effect the student experience.

Additionally, it is necessary to note that students requested the ability to use the application across multiple platforms in order to properly evaluate the interactive properties of colors in the space in which their design work would be viewed. For example, if a student designed an application to be viewed on a screen that is 640x480 pixels, they would like to experiment with various color interactions on that size screen. While a large scale touch screen application was engaging, the effect of the interaction of colors is not the same when being viewed on a much smaller, more intimate screen.

9.4 Suggestions for Future Testing

The experimentation of several interactive prototypes could potentially be used as options for enhancing different tasks in digitally manipulating color. A different concept for each prototype allows for a wider evaluation of the effectiveness of each prototype and create a more creative and exploratory experience for the final product. The difficulties that advanced technology presents can prohibit the completion of several conceptual prototypes. It would be interesting to examine the effectiveness of contracting the knowledge and
abilities of one or two computer science students to assist in creating fully functional prototypes to strengthen the results of this research and to have the ability to create a final product for usability analysis and investor presentations.

While animations and paper prototyping were effective in this initial evaluation for proposal purposes, it would be necessary to create a fully functioning prototype to further assess the interactive components of the application.

The above work and findings were a result of investigating the use of digital tools in an educational settings. A considerable amount of planning was completed in order to use appropriate methodologies to better understand the needs of students in design programs studying color in the additive space. When reflecting on the process that led to the final recommendations and design, I believe that it can be used in the design of future digital environments as well as expanding the final solution to allow for more advanced exercises around the interaction of color in the digital space.

Moving forward, this process can easily be applied to the development of other, similar foundational exercises in design curriculum. We will continue to learn, but this thesis research has positioned us in a good place to spring board someone into the next iteration of research. As technology progresses, designers will become completely enveloped in the digital arena, professionally and educationally. There is no doubt that designers will be impacted by the digital interactions they have in our everyday lives as well. With a process similar to the one outlined in this document, we can ensure that the use of interactivity in education will be user-friendly, comprehensible and inspirational.
Appendices and Bibliography

Appendix A: Pilot Study Consent Form

CONSENT FORM

The purpose of this study is to evaluate the usability of the interactive color theory application. The study will take approximately 15-30 minutes.

I understand that I will perform the following activities:

- Read questions and instructions
- Think out loud while
- Discuss positive and negative aspects of the instructions
- Provide answers to the questions in questionnaires

While I am participating in the usability test, I further understand that:
- My first name, photograph, and video footage will be used in a summary of the final results that will be provided to a representative of the OSU Design Research Team.

Compensation for Participation
I will not be compensated for my participation.

Freedom to Withdraw
I realize that research participation is completely voluntary. I understand that I am free to refuse to participate in this study or withdraw at any time. There is no penalty for either non-participation or withdrawal.

Availability of Investigators
If I have concerns or questions about the research, the Investigators can be contacted at ______________________.

Consent
My signature below indicates that I consent to participate in this research investigation.

___________________________________                             ______________________________________
participant name (print)                        participant’s signature                                        date
PHOTOGRAPHY, VIDEO & AUDIO RECORDING RELEASE FORM

The OSU Design Research Team will videotape, audio record, and photograph this workshop. These tapes and photos will be used for research purposes only. They will not be used commercially.

Please check off one or both of the statements below, then sign and date.

Thank you.

☐ I allow the OSU Design Research Team to videotape, audio record, and photograph me in this workshop session for research purposes.

☐ I allow the OSU Design Research Team to use the photos from this session in their research summary as well as for potential conference materials (papers or presentations) in the future.

___________________________________                             ______________________________________  
participant name (print)                        participant’s signature                                        date
Appendix C: Pilot Study Checklist for Session

**CHECKLIST FOR SESSION**

This is a checklist for the graduate teaching associates, based around the method that has worked for design researchers in the past. It covers all the major points for running a research session such as this.

- Collect consent forms and start videotaping. (set up camera to tape the interaction)
- Introduce the module and it’s purpose. (educating students about the interaction of color on the computer)
- Mention that the exercise formats are similar to the analog exercises.
- Give the participants a brief overview of basic system mechanics.
- Two facilitators should start playing with the participants, like coaches.
- Facilitators should introduce module concepts when they become important.
- When the participants have a grasp of the system, back off (but stay near for questions)
Appendix D: Pilot Study Guidelines for Observer(s)

**GUIDELINES FOR OBSERVER(S)**

This is essentially a list of questions to be answered by the observer (or observers) of the testing sessions. These are the major questions answered, but additional information is welcomed and encouraged.

**Key things to pay attention to and take notes on while observing the first interaction:**

1. Are there any aspects of the system that are not clear to the participants or facilitators?
2. Are the participants generally interested in the interaction?
3. What do the participants respond the most to (positively and negatively)?
4. Do the participants generally seem to be having fun?
5. How long is the exercise session?
6. Do they want to try another exercise? Explain.

**Key things to pay attention to and take notes on while observing subsequent interactions of the system:**

1. How long is the session?
2. Do they seem to navigate freely? Explain.
3. How do they explain the module to other participants?
4. Do they complete the exercise correctly? Do they give up? Explain.
Appendix E: Pilot Study Investigator Script

Thank you for participating in my usability study. My name is Lindsay, and I will be working with you today. I am testing the ease of use of this interactive color theory module, designed to enhance the learning experience of color theory, as well as assist design students in understanding the interaction of color in the digital setting. Please keep in mind during the test that your solutions to the color exercises are not what I am evaluating. I am conducting this test in order to determine whether students are able to easily understand the interaction of the interface, if this is an effective teaching medium for the material taught in color theory courses and whether or not this module is actually enhancing the learning experience. I am also trying to determine what problems users may encounter, if any, while interacting with the application. During the test, you will be asked to answer questions about your experience. While you are examining the interface, I will be watching and taking notes.

(User will receive a packet which includes the following: Consent form, Photography & Video Release form, background questionnaire, and Usability questionnaire)

Please talk aloud as you are examining the screens. Also, feel free to ask questions during the session. Do you have any questions before we begin?

First, you will fill out a pre-test questionnaire. The rest of the testing session will be comprised of a series of screens from a prototype that will be developed in the near future. After you complete the session, I will ask you questions about your experience based on the interface and how well you understood the goals of the learning module and if the interface was clear. You will then fill out another questionnaire. At the end, we will have a discussion period where you will be given the opportunity to ask questions and comment on the design.

Again, please keep in mind we are not testing you, but are just looking for feedback regarding the interface and the learning module as a whole. There are no right or wrong answers here, so just try to have fun. These screens have not been tested with people, and there may be changes that need to be made. Please be honest with your positive and negative thoughts.

(Participant will fill out Pre-test Questionnaire)

Thank you for completing the Pre-test Questionnaire. I would like to remind you to please think out loud as you are working. For example, if you are would normally select a button while going through the learning module, say it out loud and say anything that might come to mind. For example, if you think something is confusing, please say so. On the other hand, if you find something to be exceptionally clear, these comments are welcome, too. Your comments will help me understand what students are thinking and doing and where they might run into problems.

Let's begin.
# Appendix F: Pilot Study Feedback Questionnaire

## Interactive Color Theory

### Feedback Questionnaire

Please answer the following questions to the best of your ability, reflecting on the interface that was presented to you. Feel free to ask questions and offer suggestions, your opinion matters!

I am a...
- [ ] freshman
- [ ] sophomore
- [ ] junior/senior
- [ ] grad student/faculty/professional

Are you currently enrolled or have you taken Color & Communication 310 or a similar color course?
- [ ] yes
- [ ] no

Are/were you a Design major?
- [ ] yes
- [ ] no

If so, what type of Design are you interested in pursuing a career in when you graduate?
- [ ] print
- [ ] animation
- [ ] interior
- [ ] graphic
- [ ] web
- [ ] motion graphics
- [ ] industrial
- [ ] other, ___________

How often do you use the computer for your Design work (at home, in-class, any design project)?
- [ ] every day
- [ ] not very often, monthly
- [ ] a couple times a week
- [ ] rarely or never

How comfortable are you using common graphic software (ex. Adobe Photoshop)?
- [ ] very comfortable
- [ ] not comfortable
- [ ] comfortable
- [ ] I have never used them/don’t know
Appendix G: Pilot Study Task Walkthrough

**TASK WALKTHROUGH**

**on home page:**
Which button would you touch to try some exercises similar to the ones you have done in-class?

What do you think the functions of the other buttons are?

Why would it be necessary to have an account that you log in to in order access the system?

Does this aspect bother you? Why?

**secondary pages:**
Are the buttons labeled clearly?

Are any buttons labeled unclearly? How?

Do you see any items (buttons) on the screen that do not make sense?

Are the sizes of the buttons legible?

How does your finger fit on the buttons when you touch them?

Is the text legible?

How would you rate the level of contrast on the screen? Are you having trouble reading any of the items?

**exercise pages (2):**
Is it clear as to what your options are for manipulating the color?

Do you understand the labels on the interface?

Do you feel as though you would be able to freely navigate and manipulate the interactions of the colors during these exercises without pressure?

Is there anything you do not understand or do not like? Why?

**comparison pages:**
Do you like the fact that you can compare your results to the rest of your peers?

Do you understand the labels on this page?

Do you feel like if you are unhappy with a color scheme that you can easily make changes?

If you liked the colors you chose do you see an option for saving them for future digital projects? How? Why?

If you wanted to try an exercises from a different lesson, how do you think you could get there?

**overall:**
Is there any point where you were unsure as to what to do? Why?

Is there anything you would add to or subtract from in order to improve the experience of this application?

Is this something you would enjoy using during class time?

Is this something you would use at home, if given the choice?

Is this something you would use at home, on any other design projects? How? Why?
Appendix G: Pilot Study Post Session Conversation Guide

POST-SESSION CONVERSATION GUIDE

After the Presentation:

In the remaining few minutes, I’d like to discuss your experiences. Please share any comments you may have. Would you discuss any elements that you found easy or difficult to understand? Describe any aspects of the interface that you found positive or negative.

How well do you think you understand the concept of the learning module?

Do you think the navigation in the interface was clear and easy to follow?

Please discuss any parts of the interface that are unclear.

Can you foresee any difficulty for the students of Color 310 using this module to learn about digital color interaction?

How would you feel if this was incorporated into your education as a supplement to traditional class room techniques of learning about color theory?

Thank you for coming today and for participating in the usability study. Your time is valuable, and I appreciate your contribution.

(Investigator – turn off all recording devices and review/update notes)
Appendix H: Applying Learning Theory to Interactive Media Survey

Applying Learning Theory to Interactive Media

Developing effective educational experiences requires an understanding of both learning theory and what appeals to learners. I will be conducting a brief discussion on how YOU learn best and how YOU enjoy learning. Thanks in advance for your time.

* Required

Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research? *

- check all that apply
  - wikipedia
  - encyclopedias
  - library books
  - ask your mom
  - get together as a group to discuss the topic
  - google, yahoo, or other search engine
  - design blogs and forums
  - play a game
  - look at pictures of other remote controls
  - read magazine articles or journal entries about the topic
  - make a movie about the topic
  - Other: [ ]

Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content? *

- Select the best answer.
  - take notes
  - watch a video
  - hands on - guided
  - hands on - free play
  - instructor demonstration
  - quiz or test
  - Other: [ ]

You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc), what 3 websites will you visit to have some fun? Why are they fun for you? *

Try to think of sites that offer high degrees of interactivity.

https://docs.google.com/spreadsheets/d/1DfJ2UWr-yZEBtsXljcFZOLiuSzlJIM066M...
What is the coolest website or application you use? Why? *
Try to think of the functionality or what you learn using the website/app.

Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?

Please briefly describe the worst learning experience you have ever had. *

Please briefly describe the best learning experience you ever had. Why was it so special? *
Appendix I: Applying Learning Theory to Interactive Media Results Summary

5/23/12

19 responses

Last Name
Luo  Wong  Khanna  Goh  Ang  Jumil  Imren  Kar Siah  Ish  Xue  Lim  Kin  Kwek  Norahini

First Name
Jia  Rachel  Nikita  Weisang  Kenneth  Metowen  Alfred  Yeo  Min Hwa  Benjamin  Shing Yu  Lim  Wien  Shyi  Melina

Email Address
luoje0012019@hotmail.com  xingraykeithab@gmail.com  nikikhaanne10@gmail.com  rosowen@hotmail.com  alphahadi6@gmail.com  amyxyeswen@hotmail.com  alia88@gmail.com

Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?

<table>
<thead>
<tr>
<th>Tool</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wikipedia</td>
<td>9 (47%)</td>
</tr>
<tr>
<td>encyclopedia</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>library books</td>
<td>6 (32%)</td>
</tr>
<tr>
<td>ask your mom</td>
<td>3 (16%)</td>
</tr>
<tr>
<td>get together as a group to discuss the topic</td>
<td>15 (79%)</td>
</tr>
<tr>
<td>google, yahoo, or other search engine</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>design blogs and forums</td>
<td>13 (68%)</td>
</tr>
<tr>
<td>play a game</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>look at pictures of other remote controls</td>
<td>16 (84%)</td>
</tr>
<tr>
<td>read magazine articles or journal entries about the topic</td>
<td>7 (37%)</td>
</tr>
<tr>
<td>make a movie about the topic</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Other</td>
<td>4 (21%)</td>
</tr>
</tbody>
</table>

People may select more than one checkbox, so percentages may add up to more than 100%. 

Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content?

<table>
<thead>
<tr>
<th>Method</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>take notes</td>
<td>7 (37%)</td>
</tr>
<tr>
<td>watch a video</td>
<td>2 (11%)</td>
</tr>
<tr>
<td>hands on - guided</td>
<td>6 (32%)</td>
</tr>
<tr>
<td>hands on - free play</td>
<td>3 (16%)</td>
</tr>
<tr>
<td>instructor demonstration</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>quiz or test</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Other</td>
<td>0 (0%)</td>
</tr>
</tbody>
</table>

You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc), what 3 websites will you visit to have some fun? Why are they fun for you?

Facebook: You can know what’s around in few seconds  www.dailic.com (it’s a design blog that gives me a lot of inspiration) best of all they update quite regularly!  www.urban outfitters.com [Just to see if there are nice things on sale ] ha ha ha I don’t really surf the internet for fun. My blog: I go to write and code at the same time. Design sites/blogs: Great ideas, fun and educational at the same time. Kongregate: Fantastic flash games for free. Archdaily 05/01/08 My own blog: from two informative and helpful with study, the last one is about having fun and jotting down personal the ... 

What is the coolest website or application you use? Why?

Tumble.com: Usually I will add the kind of jargon with the same interest as mine and get to see their interesting posts and pictures with just a click! coolest app would be the stylo notes app.

https://docs.google.com/spreadsheet/gform?key=0AkpoKNSG0v4dF8saWRYZE8tSXjdJcFZOLUixS...
Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?

Yes. A little bit hard to catch the mechanisms of the tools however with a lot of practice and regular applications being done, it is much easier to master the software not in college. Yes, self-paced learning, but sometimes very difficult to find means to clarify doubts. I never use that before. None. I learn InDesign through online tutorial; it’s very easy to follow as everything is clearly explained through animation step by step. It’s very interactive, but we can’t ask the online “tutor” for help if we have any. I don’t think I can remember. 3D Solidworks. Strengths: easy to use, interactive, etc.

Please briefly describe the worst learning experience you have ever had.

Once I studied basic photography and it was my first time handling DSLR camera. I have no prior knowledge about the camera but however, the lecturer who taught me used to scold me whenever I posed him the same question as I still don’t get it. Since then I have asked him again and learn on my own. I had a chance to learn dreamweaver in school (it’s a while back, and it was so noticeable because the lecturer forced us to use specific colours that obviously clashed with each other, plus the typology that we were allowed to use was so ugly [can’t recall what it was called]). I McB I hated the an...

Please briefly describe the best learning experience you have ever had. Why was it so special?

Best class would be the most interactive class where you get to do hands-on work on the spot and the teacher will come to us and praise or critique our work. I remember my 2D Illustration class where the assignment should be done in class and should be handed on the same day. We were drawing and painting in a circle and I truly enjoyed the class because I love drawing. The lecturer went around and saw the students’ work and he praised my work which boosted up my confidence. The best learning experience for me would be how I picked up Photoshop. I didn’t have a teacher to teach me what tools I ...

https://docs.google.com/spreadsheet/gform?key=0AAnKpoKNFSGW4dDFlaW5yZEBtSxjcfZ0LixS...

129
<table>
<thead>
<tr>
<th>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</th>
<th>Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content?</th>
<th>You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc), what 3 websites will you visit to have some fun? Why are they fun for you?</th>
<th>What is the coolest website or application you use? Why?</th>
<th>Please briefly describe the worst learning experience you have ever had.</th>
<th>Please briefly describe the best learning experience you ever had. Why was it so special?</th>
<th>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</th>
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<tbody>
<tr>
<td>google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls, read magazine articles or journal entries about the topic</td>
<td>Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content?</td>
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<td>Please briefly describe the worst learning experience you have ever had.</td>
<td>Please briefly describe the best learning experience you ever had. Why was it so special?</td>
<td>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</td>
</tr>
<tr>
<td>watch a video</td>
<td>Once I studied basic photography and it was my first time handling DSLR camera. I have no prior knowledge about the camera but however, the lecturer who taught me used to scold me whenever I posed him the same questions as I still don't get it. Since then I hate asking him again and learn on my own :)</td>
<td>Facebook. You can know what's around in few seconds</td>
<td>Tumblr.com. Usually I will add the kind of person with the same interest as mine and get to see their interesting posts and pictures with just a click!</td>
<td>Best class would be the most interactive class where you get to do hands-on work on the spot and the teacher will come to us and praise or critique our work. I remember my 2D illustration class where the assignment should be done in class and should be handed on the same day. We were drawing and painting in a circle and I truly enjoyed the class because I love drawing. The lecturer went around and see the students’ work and he praised my work which boost up my confidence :)</td>
<td>Yes. A little bit hard to catch the mechanism of the tools however with a lot of practice and regular applications being done, it is much easier to master the software</td>
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<td>Question</td>
<td>Answer</td>
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<tr>
<td>Your class is learning a new subject in class today. You will be</td>
<td>I had a chance to learn Dreamweaver in school quite a while back, and it was so restrictive because the teacher forced us to use specific colours that obviously clashed with each other, plus the typeface that we were allowed to use was so ugly (can't remember what it was though). I really hated the end result and swore never to use Dreamweaver, which is quite a pity, I think.</td>
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<tr>
<td>required to remember the information reviewed as well as use the</td>
<td>Please briefly describe the worst learning experience you have ever had. Why was it so special?</td>
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<tr>
<td>information in future projects. What is the best way for you to</td>
<td>The best learning experience for me would be how I picked up Photoshop. I didn't have a teacher to teach me what tools there were so I had to try each one out by myself. I liked that I had no time limit and could do whatever I wanted. It was special because I would discover a new feature about Photoshop each time I used it and get very excited.</td>
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<tr>
<td>remember the content?</td>
<td>Please briefly describe the best learning experience you have ever had. Why was it so special?</td>
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<tr>
<td>Your class has been given the task to design a new remote control</td>
<td>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</td>
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<tr>
<td>specifically for children. What tools do you use to begin your</td>
<td>Wikipedia, get together as a group to discuss the topic, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls, take notes.</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>research?</td>
<td><a href="http://www.dtail.com">www.dtail.com</a> (it's a design blog that gives me a lot of inspiration! best of all they update quite regularly!)</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td><a href="http://www.urbanoutfitters.com">www.urbanoutfitters.com</a> (just to see if there are nice things on sale haha)</td>
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<td></td>
<td>hmmm I don't really surf the internet for fun</td>
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<td></td>
<td>coolest app would be the sticky notes app on my smartphone, I like how I can customise typefaces and colours etc (helps to make reminders look nice so that I will look at them haha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What is the coolest website or application you use? Why?</td>
<td>I had a chance to learn Dreamweaver in school quite a while back, and it was so restrictive because the teacher forced us to use specific colours that obviously clashed with each other, plus the typeface that we were allowed to use was so ugly (can't remember what it was though). I really hated the end result and swore never to use Dreamweaver, which is quite a pity, I think.</td>
<td></td>
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<td></td>
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<tr>
<td>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</td>
<td>Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as the information in future projects. What is the best way for you to remember the content?</td>
<td>You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc.), what 3 websites will you visit to have some fun? Why are they fun for you?</td>
<td>What is the coolest website or application you use? Why?</td>
<td>Please briefly describe the worst learning experience you have ever had.</td>
<td>Please briefly describe the best learning experience you ever had. Why was it so special?</td>
<td>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</td>
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<td>---</td>
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</tr>
<tr>
<td>library books, get together as a group to discuss the topic, look at pictures of other remote controls</td>
<td>My blog: I get to write and code at the same time. Design sites/blogs: Great ideas, fun and educational at the same time. Kongregate: Fantastic flash games for free.</td>
<td>Wordpress. Excellent blogging tools.</td>
<td>Lectures, the lecturer went non-stop for 3 hours straight.</td>
<td>Outdoor lecture cum movie. Field trips are to best as I feel that hands-on learning is the best way. The school actually brought as to watch a movie in a cinema with comfy seats for a show about green technology.</td>
<td>Yes. Self paced learning, but sometimes very difficult to find means to clarify doubts.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>hands on - guided</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Archdaily DUDYE My own blog</td>
<td></td>
</tr>
<tr>
<td>First two are informative and helpful with study, the last one is about having fun and jotting down personal thoughts.</td>
<td>Adobe Indesign helps a lot in my work.</td>
</tr>
<tr>
<td>hands on - free play</td>
<td></td>
</tr>
</tbody>
</table>

|  |  |  |  |  |  |  

132
<table>
<thead>
<tr>
<th>Question</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your class has been given the task to design a new remote control</td>
<td>ask your mom, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls hands on - guided</td>
</tr>
<tr>
<td>specifically for children. What tools do you use to begin your</td>
<td>Wordpress, Last.fm, 1Dskeching.com. Other than Facebook, these 3 websites allow me to interact with other people in terms of writing, music and innovation respectively.</td>
</tr>
<tr>
<td>research?</td>
<td>Photoshop. I’ve learnt a lot from photoshop and I know I have more to discover. It has helped in my artworks, submissions and photo amendments. It creates wonders!</td>
</tr>
<tr>
<td>Your class is learning a new subject in class today. You will be</td>
<td>Boring lecture with speeches from tutorial in the first few minutes turning into gibberish blabbering in the following hours. No hands-on activity so students could not absorb what was taught.</td>
</tr>
<tr>
<td>required to remember the information reviewed as well as use the</td>
<td>Please briefly describe the worst learning experience you have ever had. Why was it so special?</td>
</tr>
<tr>
<td>information in future projects. What is the best way for you to</td>
<td>Please briefly describe the best learning experience you have ever had. Why was it so special?</td>
</tr>
<tr>
<td>remember the content?</td>
<td>My best learning experience was on geometric volume in my primary school days. It was the most memorable experience I’ve had. We learnt about volumes, and our teacher brought in different types of containers and a pile of colored sand. We were supposed to find out the relation of the volumes with different geometries and a theory-based topic becomes something that is so easy to remember.</td>
</tr>
<tr>
<td>You have 30 minutes of free time, and all of your assignments are</td>
<td>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</td>
</tr>
<tr>
<td>complete. Beyond typical social media sites (Facebook, Twitter, YouTube,</td>
<td></td>
</tr>
<tr>
<td>etc), what 3 websites will you visit to have some fun? Why are they</td>
<td></td>
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<td>fun for you?</td>
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<td>What is the coolest website or application you use? Why?</td>
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<td>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</td>
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<td>google, yahoo, or other search engine</td>
<td>watch a video</td>
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| wikipedia, library books, get together as a group to discuss the topic, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls | take notes | Deviantart.com - Can see a lot of artworks - Can join roleplaying groups where one can roleplay by drawing - Join Original Characters Tournaments Neopets.com - Games topwebcomics.com - Checking out webcomics http://demo.fb.se/e/ikea/comemintof - You get to move the characters by tapping the keyboard. Basically, the characters move using music... so you can upload music unto the site and see the characters move according to the music | i can’t remember but basically, the worst learning experience is when i’m unable to absorb what the person is talking about because of the way he/she teaches (Just reading, no activities) or because of the audience (noisy) | I can’t remember any best learning experiences... but I think a good learning experience is when activities are involved and the teacher tries to interact with people in the course so none feels left out. | I don’t think I can remember...
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<th>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</th>
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<th>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</th>
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<td>Look at pictures of other remote controls</td>
<td>Skype go on gossip sites, Perez iton, eonline... maybe some designe websites such as notcot.org</td>
<td>I don't have a preference for any website, at least application wise. Indesign is quite good as I only learnt how to use it recently</td>
<td>I think the worst is learning from a long word document, simply by just reading it without any diagrams</td>
<td>I can't remember, but most likely something along the lines of a more kinaesthetic approach.</td>
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<td>Take notes</td>
<td><a href="http://www.mangaflex.com">www.mangaflex.com</a></td>
<td>This is due to the simplistic use of flash to demonstrate movement, story and role play. It also shows how a simple flash demonstration of maybe 1 minute can take a lot of time to do.</td>
<td>When I read a self-help book on impressions and everything the author had to offer was common sense and it wasn't much of a help at all.</td>
<td>When I sat through a seminar on leadership and the details of good human resource management and inter-personal communication was discussed.</td>
<td>3D SolidWorks. Strengths: easy to use, interactive, fascinating to explore. Weaknesses: Slow to respond at times, certain features can take a lot of time to explore.</td>
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<td>Question</td>
<td>Answer</td>
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<td>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</td>
<td>Wikipedia, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls</td>
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<td>Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content?</td>
<td>Usually I will stick with Facebook, chat with my friends or play computer games. If purely websites only, I will visit websites with flash games, that's about it.</td>
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<td>You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc), what 3 websites will you visit to have some fun? Why are they fun for you?</td>
<td>Rockmelt browser. It integrates feeds from Facebook and Twitter into the browser itself so I can check my news feeds anytime. Also integrated is Facebook Chat, which I can use anytime. I also can add feeds from websites so I know when they are updated.</td>
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<td>What is the coolest website or application you use? Why?</td>
<td>A boring lecture. You feel sleepy, you can't concentrate and nothing goes in. For better or worse, there is still the webcast online to watch after the lecture. However, the webcast makes me feel sleepy too.</td>
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<td>Please briefly describe the worst learning experience you ever had. Why was it so special?</td>
<td>In general, the lessons I have taken in this course so far. The small class size facilitates learning, the teachers are engaging and interesting, the classes are lively. This fosters interest and enthusiasm and the addition of hands-on work, live demonstration, and videos help to ensure lessons are not dry.</td>
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<td>Please briefly describe the best learning experience you ever had.</td>
<td>Nope,</td>
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<td>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</td>
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<td>ebay</td>
<td>You can buy remote controls online.</td>
<td>google</td>
<td>What is the coolest website or application you use? Why?</td>
<td>google</td>
<td>The recent lecture based computer aided learning via lectures. A CAD lesson has to be done in computer lab and not through lectures, hence the practical lesson can be followed easily by students on a step-by-step basis.</td>
<td>The buttons lesson by Dr Christian. This allowed for self discovery of ones own design philosophy with just using simple shapes. This allows for different functions from the same shape or similar design.</td>
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<tr>
<td>amazon</td>
<td>Amazon offers a wide range of remote controls for children.</td>
<td>wikipedia, get together as a group to discuss the topic, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls, read magazine articles or journal entries about the topic, study how kids use normal remote control</td>
<td>eBay</td>
<td>eBay</td>
<td>eBay</td>
<td>Yes, e-learning programme by a lecturer. Well it’s strength is the answers to questions asked can be derived directly from the programme. The major weakness is there usually no real learning involved as students don’t research further or that there is no one around to answer more enquiries.</td>
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<td>armorgames.com</td>
<td>Take notes on the information.</td>
<td>armorgames.com</td>
<td>Well although ebay and amazon may not be the normal mode of fun for most people, I do enjoy looking through offers, new items and items that are not available to collect or to fulfill my hobbies like high end earphones. As for armorgames.com it’s to pass time quickly by playing simple flash based games.</td>
<td>google</td>
<td>google</td>
<td>Yes, e-learning programme by a lecturer. Well it’s strength is the answers to questions asked can be derived directly from the programme. The major weakness is there usually no real learning involved as students don’t research further or that there is no one around to answer more enquiries.</td>
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<td>Notcot.org, Oneshift.com, Foodpomdaily.com</td>
<td>Facebook! It’s definitely the coolest. It’s amazing how connected it makes everyone. If I find a cool website, I’ll save it and share it with my friends. A cool video on youtube or an amazing photo on flickr? No problem. Some friends of mine study across the world. I see their life through the photos they’re tagged in, they see mine. I see how their looks change, like if they don’t shave or change their hairstyle, and it helps so I don’t think they look like strangers when they get back home. Vice versa, they see my life too so though</td>
<td>I had a Physics teacher who is probably very good at Physics. He wasn’t good at putting his knowledge across and his lessons were not very clear. He answered questions very quickly and briefly, expecting me to know more than I did. And when I showed that I didn’t know as much as he thought I did, he looked frustrated. So naturally, I got frustrated with him and the subject.</td>
<td>I had an amazing Literature teacher who knew everything! He spoke and read Latin. He also knew so much about everything in general. We were on a Lit Trip to the UK and he was telling us more about the places we were visiting than the tour guide himself. The way he spoke while he was telling us all this information was as if he was telling a story so I hung onto every word he spoke. Besides being a genius tomb of knowledge, he was also round and smiley and friendly. During lessons, he’d make us feel as if he were bringing us</td>
<td>We use an online portal where we can find degraded or online modules of lectures at our lectures notes that they handed out during the class and also the slides that the lecturers present. This helps when the time comes for revision or if I find the slides or materials very interesting and want to keep them for future reference. I can just download it onto my computer. However, they tend to be a little bit complex and interfaces that make it hard for both the students and lecturers to use, sometimes resulting in under-use. Also, complex</td>
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<td>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</td>
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<td>wikipedia, get together as a group to discuss the topic, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls, read magazine articles or journal entries about the topic</td>
<td>they have lots of photos for the reviews and you can just click on the photo to go to the next photo instead of find a small link that may not be in the same frame as the picture. Foodomdally.com: I like how you just see one high resolution picture of a random dish and the description is hidden in the picture. Also, you only need to click on that picture to see more delicious pictures satiate your inner foodie desires.</td>
<td>the photos they're tagged in, they see mine. I see how their looks change, like if they don't shave or change their hairstyle, and it helps so I don't think they look like strangers when they get back home. Vice versa, they see my life too so though we're so far away, it doesn't really seem so. Amazing I must say. Also, it makes snail mail novelty, so if I'm short of birthday ideas, I send a pretty postcard and it's settled. :)</td>
<td>Please briefly describe the worst learning experience you have ever had. Why was it so special?</td>
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<td>hands on - free play</td>
<td>I had a Physics teacher who is probably really good at Physics. He wasn't good at putting his knowledge across and his lessons were not very clear. He answered questions very quickly and briefly, expecting me to know more than I did. And when I showed that I didn't know as much as he thought I did, he looked frustrated. So naturally, I got frustrated with him and the subject.</td>
<td>through the writer's mind. It wasn't a lecture though. He did encourage us to speak up and though he probably had thought of everything we could come up with, he made us feel like we discovered something completely new each time so though I was intimidated by his genius, I wasn't afraid to speak up during his lessons. Oh, he also loved it when we challenged his opinions or each others opinions.</td>
<td>Please briefly describe the best learning experience you have ever had.</td>
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<td>For future reference, I can just download it onto my computer. However, they tend to be pretty complex interfaces that make it hard for both the students and lecturers to use, sometimes resulting in under-use. Also, complex interfaces and my laziness result in me not referring to the course materials as I should. This usually ends up with me having a harder time than I should with that particular topic.</td>
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<td>Question</td>
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<td>Your class has been given the task to design a new remote control</td>
<td>library books, google, yahoo, or other search engine, look at pictures of other remote controls, observe children playing with remote controls, or operating any form of handheld systems. hands on - guided</td>
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<td>specifically for children. What tools do you use to begin your research?</td>
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<td>Your class is learning a new subject in class today. You will be</td>
<td><a href="http://www.superfuture.com">www.superfuture.com</a> - website with forum interactivity on fashion, culture, and everything else</td>
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<td>required to remember the information in future projects. What is the</td>
<td><a href="http://www.aintitcool.com">www.aintitcool.com</a> - humour-filled website on films with trailers, articles, and comments section for readers</td>
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<td>best way for you to remember the content?</td>
<td><a href="http://www.gametrailers.com">www.gametrailers.com</a> - place to get videos on upcoming games etc</td>
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<td>You have 30 minutes of free time, and all of your assignments are</td>
<td>Google earth. I can be the eyes of the satellite!</td>
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<td>complete. Beyond typical social media sites (Facebook, Twitter,</td>
<td>Mosty from my Polytechnic days and at the moment my University days. They were and are all very hands-on. Not to say books aren’t important, but it is a good complement to have on-the-spot learning instead of only forcing information down the throats of students.</td>
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<td>YouTube, etc), what 3 websites will you visit to have some fun? Why</td>
<td>Mostly from my Polytechnic days and at the moment my University days. They were and are all very hands-on. Not to say books aren’t important, but it is a good complement to have on-the-spot learning instead of only forcing information down the throats of students.</td>
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<td>are they fun for you?</td>
<td>Mosty from my Polytechnic days and at the moment my University days. They were and are all very hands-on. Not to say books aren’t important, but it is a good complement to have on-the-spot learning instead of only forcing information down the throats of students.</td>
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<td>education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</td>
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<td>Class &amp; Information</td>
<td>Research Method</td>
<td>Description</td>
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<td>Class is learning a new subject. You will be required to remember the information in future projects. What is the best way for you to remember it?</td>
<td>Instructor demonstration</td>
<td>wikipedia, library books, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls, read magazine articles or journal entries about the topic</td>
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<td>You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc), what 3 websites will you visit to have some fun? Why are they fun for you?</td>
<td>hands on - guided</td>
<td>notcot.org to see some other designs mangastream to have my weekly dose of manga EDMW (a singapore social forum) to check out on the latest gosips and laughter</td>
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<td>Please briefly describe the worst learning experience you ever had. Why was it so special?</td>
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<td>it was back in my secondary school days when there was a video of the person speaking and another person which displayed his slides. It was entertaining and it managed to capture my interest for the entire course of study.</td>
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<td>Please briefly describe the best learning experience you ever had. Why was it so special?</td>
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<td>It was boring and lengthy, there could be more interactive stuff to keep the users attention</td>
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Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience? | Yes. Strength: I can do it at my own leisure, fast-forward and replay as I please. Weakness: It’s a tad troublesome, as the internet allows more seamless access to materials nowadays. Hence there’s no need to carry a disc around.
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<td>library books, ask your mom, get together as a group to discuss the topic, go to blogs and forums, look at pictures of other remote controls, wikipedia, encyclopedias, get together as a group to discuss the topic, google, yahoo, or other search engine, look at pictures of other remote controls, read magazine articles or journal entries about the topic, make observations of kids.</td>
<td>nitrome.com minidips.com both are game sites thus allowing for fun and relaxation hi5.com because its a social networking site</td>
<td>facebook it has practically everything I need for good communication with friends, ranging from status update, groups, email, conversations and photo tagging.</td>
<td>There's not really a bad experience for me. The cd-rom just could not start up the program.</td>
<td>I can't exactly remember the best experience but there was once that I used a CD-rom software during a workshop that enabled me to learn piloting an aircraft virtually. It was a course related to physics but we had a lot of fun and learnt many new things at the same time.</td>
<td>Yes. The materials we learn are interesting and encourage more interactivity, but the software (especially from CD-roms) are slow to load or may not be able to load.</td>
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<td>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</td>
<td>Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content?</td>
<td>You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc), what 3 websites will you visit to have some fun? Why are they fun for you?</td>
<td>What is the coolest website or application you use? Why?</td>
<td>Please briefly describe the worst learning experience you have ever had.</td>
<td>Please briefly describe the best learning experience you ever had. Why was it so special?</td>
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</tr>
<tr>
<td>[wikipedia, design blogs and forums, look at pictures of other remote controls, read magazine articles or journal entries about the topic hands on - free play]</td>
<td>FontStruct The website is essentially an online font creation program. I don't need to download any software as I can use the font creator on the website itself. It's really easy to use and its pretty fun as well. After creating the font for myself, I can share it with other people using the website. I can also browse the archives to look for good fonts that other people have created and posted.</td>
<td>Engineering lectures at NUS. The professor for the engineering module I took this semester was very weak in lecture delivery. He was not engaging and was excruciatingly slow. He would take 10 minutes to explain a basic idea I could understand in under a minute. The dry lecture content did little to help him.</td>
<td>My first and second year in junior college. When I was 15, was admitted into a new academic programme in Singapore called the Integrated Programme. Students in the programme are allowed to skip our O'Levels and my school experimented with new ways of teaching. Lessons were mostly module based (like university) and lesson content was highly integrated. For example, a module on Space would integrate the concepts of math, physics and astronomy.</td>
<td>Yes. I never liked digital-based learning. Always preferred the traditional lecture or lesson with a teacher. Digital learning is a solitary process which restricts the ability of one to learn more. Classroom learning thrives on the fact that there are classmates for active discussion and learning.</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
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<td>-------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
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</tbody>
</table>
| What are the tools you use to begin your research?                      | **animations.**
Friendly and easy-to-use interface.
Keeps me updated with the design field.
3. Gizmodo.com Lots of cool gadget-related articles and etc. |
<p>| Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research? | hands on - free play |
| Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content? | creator on the website itself. It's really easy to use and its pretty fun as well. After creating the font for myself, I can share it with other people using the website. I can also browse the archives to look for good fonts that other people have created and posted. |
| You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc.), what 3 websites will you visit to have some fun? Why are they fun for you? | the engineering module I took this semester was very weak in lecture delivery. He was not engaging and was excruciatingly slow. He would take 10 minutes to explain a basic idea I could understand in under a minute. The dry lecture content did little to help him. |
| What is the coolest website or application you use? Why? | Please briefly describe the worst learning experience you have ever had. |
| Please briefly describe the best learning experience you ever had. | There was little or no emphasis on examinations. Instead, learning was mostly project based. There was no textbook. We were encouraged to learn by sourcing for the material ourselves. There was a large emphasis on creative expression. |
| Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience? | learning. Always preferred the traditional lecture or lesson with a teacher. Digital learning is a solitary process which restricts the ability of one to learn more. Classroom learning thrives on the fact that there are classmates for active discussion and learning. |</p>
<table>
<thead>
<tr>
<th>Your class has been given the task to design a new remote control specifically for children. What tools do you use to begin your research?</th>
<th>Your class is learning a new subject in class today. You will be required to remember the information reviewed as well as use the information in future projects. What is the best way for you to remember the content?</th>
<th>You have 30 minutes of free time, and all of your assignments are complete. Beyond typical social media sites (Facebook, Twitter, YouTube, etc.), what 3 websites will you visit to have some fun? Why are they fun for you?</th>
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<th>Please briefly describe the worst learning experience you have ever had. Why was it so special?</th>
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<th>Have you ever used an online or CD-ROM application during your college education in the classroom to learn course material? If so, can you remember the strengths and weaknesses of the experience?</th>
</tr>
</thead>
<tbody>
<tr>
<td>library books, google, yahoo, or other search engine, design blogs and forums, look at pictures of other remote controls</td>
<td>1) National Geographic website - I will de-stress by attempting the quizzes there.</td>
<td>SKYPE! It's simply the best innovation to keep in touch with loved ones who are miles away and I enjoy using the application — It's pretty user friendly.</td>
<td>My best learning experience was my geography classes in Junior college. It was special because, firstly, I loved the subject very much and secondly, I learnt a lot of new things during the lessons, it kept my mind occupied, constantly feeding my mind with new information about the things around me.</td>
<td>No.</td>
<td>No.</td>
<td>No.</td>
</tr>
</tbody>
</table>
Appendix K: Color Vocabulary: Basic Color Wheel Handout
Appendix L: Color Vocabulary: Properties Handout
Appendix N: Color Basics Adobe Illustrator Exercise

**Color Basics**

Use the color wheel to alter the properties of the given hues.

1. **Fill the three circles with the primary colors.**
   All other colors are derived from these 3 hues.

2. **Fill the three circles with the secondary colors.**
   These are the colors formed by mixing two primary colors.

3. **Fill the six circles with the tertiary colors.**
   These are the colors formed by mixing a primary and a secondary color.

4. **Fill the two gray circles with different hues.**
   The last circle has been filled in black.

5. **Change the saturation level of the two circles.**
   The first circle is the hue. Capture saturation for gray and the tertiary to the complement of the given hue.

6. **Change the value of the two circles.**
   The first circle is the hue. Try to create a tint and a shade of that hue.
Appendix O: Complementary Color Adobe Illustrator Exercise

Complimentary Color

Use the color wheel to define the hue and then assign the complimentary color to each hue.
Appendix P: Color Harmony Adobe Illustrator Exercise

Color Harmony

| Use the color wheel to create each color harmony. |

1. Fill the three circles with an achromatic color harmony. (A color scheme comprised of shades and tints of a single hue. This creates less contrast but more balance.)

2. Fill the three circles with any monochromatic color harmony. (Any three colors which are made by one hue and tints of that hue. These are more bold and dramatic than those in achromatic.)

3. Fill the three circles with any analogous color harmony. (Any three colors which are made by one hue and related colors. A luminous color harmony with mild contrasting.)

4. Fill the four circles with any tetradic (square) color harmony. (Four colors in a square across from each other on the color wheel. Less contrast, more balance.)

5. Fill the circles with any triadic color harmony. (Three colors of equal distance on the color wheel. This creates less contrast but more balance.)

6. Fill the circles with any complimentary color harmony. (Any two colors opposite each other on the color wheel, include tones and shades. Good contrast.)

7. Fill the circles with any split complimentary color harmony. (Three colors with one of them kept in each half of the complement of the first color wheel contrast.)

8. Fill the circles with any tetradic (rectangle) color harmony. (Four colors in a rectangle across from each other on the color wheel. Less contrast, more balance.)
Appendix Q: Simultaneous Contrast Adobe Illustrator Exercise

Simultaneous Contrast

Select any combination of three hues in order to create the illusion of four colors.

Simultaneous contrast is most intense when the two main colors are complementary colors.
Appendix R: Color Transparency Adobe Illustrator Exercise

<table>
<thead>
<tr>
<th>Color Transparency</th>
<th>Use the color wheel to alter each group of circles to create the illusion of transparency.</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Color Wheel" /></td>
<td></td>
</tr>
<tr>
<td><img src="image" alt="Circles" /></td>
<td></td>
</tr>
</tbody>
</table>
Appendix S: 3D Color Illusion Adobe Illustrator Exercise

<table>
<thead>
<tr>
<th>3D Color Illusion</th>
<th>Use the color wheel to alter each shape to create the illusion of depth using the property of value.</th>
</tr>
</thead>
</table>

![Color Wheel and 3D Shapes](image-url)
Appendix T: Simultaneous Contrast- Learning Retention and Assessment Survey

Simultaneous Contrast - Learning Retention and Assessment

After reviewing the Simultaneous Contrast application, answer the following questions to the best of your ability.

Considering how you like to learn, what are the strengths of this application?

Considering how you like to learn, what are the weaknesses this application?

Were the instructions easy to follow?
Was the wording clear? Did you ever find yourself wondering what you were supposed to do?

1 2 3 4 5 6 7 8 9 10

I was confused ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ I completed it with no problems

How might you tailor the instructions to facilitate better comprehension of the concept?

How did the interactions facilitate your understanding of the information?
By touching the screen did that help connect the mental dots on how to adjust the colors?
After reflecting the use of this application, which particular area was most memorable?

"Desaturating a color using it's complement"
Main menu of 7 different contrast exercises

Why was this function or area the most memorable?

How does the experience compare to when you did this activity in Color 310?

<table>
<thead>
<tr>
<th>I prefer using Color-Aid</th>
<th>I prefer using the Touch Screen App</th>
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</thead>
<tbody>
<tr>
<td>1</td>
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<td>3</td>
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<td>7</td>
<td>8</td>
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<tr>
<td>9</td>
<td>10</td>
</tr>
</tbody>
</table>

Why do you prefer doing the activity that way?

In considering how you best learn, how would you rate these features in order of priority?

<table>
<thead>
<tr>
<th>RGB vs CMYK color space</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Histogram</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Saved Color Selection</td>
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<tr>
<td>Palette</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Various ways to alter color</td>
<td></td>
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</tbody>
</table>
Hidden Color Wheel

First and Last Name

What is your intended profession upon graduation?

How many hours a day will you be working professionally on the computer?

How many of those hours will rely on accurate color contrast and color interaction on screen?

Kinect Feedback - what are your feelings about this game being used in the classroom to teach students the RGB color wheel and about additive color mixing? If any...

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Appendix T: Simultaneous Contrast- Learning Retentions and Assessment Results Summary

5/23/12

Summary

Considering how you like to learn, what are the strengths of this application?
The simple interface is nice. The lack of clutter compared to other sites allowing experimentation of color helps me focus on the exercise at hand. I like how it is very similar to the current manner of learning about color interaction; through trial and error. This makes it an easier mental bridge from the physical activity to the digital activity. I am easily able to navigate between the various ways of manipulating color and get immediate results instead of digging through random pieces of color-aid. This is also a cheaper option. I love the history, it would come in handy when explaining ...

Considering how you like to learn, what are the weaknesses this application?
The central circular piece doesn’t have a strong affordance, letting me know I can interact with it. Until I actually starting playing with the app, I wasn’t sure what it’s function was. Even though I really like how much I can do with color in this environment, I doubt I will remember all of the functions of the various tabs without labels. None I can see right away. In the beginning I was trying too hard to learn how the application worked to focus on what was happening ...

How might you tailor the instructions to facilitate better comprehension of the concept?
Introductory tool tips that can be revealed and hidden based on user choice would be nice. I imagine after a few uses, I will no longer need the reminder. I would strongly suggest an in-class demonstration before giving the students free reign to use the application...possibly even an introductory video showing a student completing an entire exercise from beginning to end. The mapping seemed off, especially once you rotated the color wheel, that should definitely be stationary. Indicator or easy to hide tool tips. I would make a demonstration part of the in-class lecture. Then once I get the id ...

https://docs.google.com/spreadsheet/gform?key=0AmKpoKNSGOW4dEdwe7hTNEvVQWZ3WtVcUZ...
How did the interactions facilitate your understanding of the information?
By touching the screen and getting tactile feedback, it provides a richer environment and more degrees of freedom and choices. *Students could potentially get overwhelmed by the amount of choices and get frustrated.** When you drag the larger piece, you see the color change right away. It is very clear what is happening to the color and why- due to the expanded panel on the right side of the screen. **Being able to drag the wheel up and down when adjusting the tints, shades and tonal values of the color made sense. However, when adjusting the hue, I would show a behind the scenes transition of w  

After reflecting the use of this application, which particular area was most memorable?

<table>
<thead>
<tr>
<th>Option</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main menu of 7 different contrast exercises</td>
<td>1</td>
<td>10%</td>
</tr>
<tr>
<td>RGB vs CMYK color space</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>Histogram</td>
<td>2</td>
<td>20%</td>
</tr>
<tr>
<td>My saved selection palette</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>RGB or CMYK value representation</td>
<td>0</td>
<td>0%</td>
</tr>
<tr>
<td>The subtle hidden color wheel</td>
<td>3</td>
<td>30%</td>
</tr>
<tr>
<td>Two ways to desaturate a color</td>
<td>4</td>
<td>40%</td>
</tr>
<tr>
<td>The 4 point color wheel</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

Why was this function or area the most memorable?
This was never mentioned in my color theory course. Additionally, being able to see on screen a gradient with the degrees of change happening as I make changes made it very clear what is happening when I adjust the controls. Instead of seeing a giant color wheel, I see what I am focusing on, and can easily evaluate the contrast of the colors on screen without distraction. Too many colors on screen make me confused. The formula I used to create a color would be the strongest way for me to learn within this application. Especially since there are hour different ways to manipulate the colors (hue  

How does the experience compare to when you did this activity in Color 310?

<table>
<thead>
<tr>
<th>I prefer using Color-Aid</th>
<th>1</th>
<th>0%</th>
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</table>

https://docs.google.com/spreadsheets/d/1j3vGOW1j3WDVicUZ...
Why do you prefer doing the activity that way?

I don't have to worry about making mistakes; emphasis is on my selection of colors, rather than precision and measurements. This is also a reusable course, and my choices are readily able to recall. I can see the formula behind the scenes that created the contrast relationship between the colors I chose. It is easier to see everything on one screen. Additionally, all of the colors I want to use are represented here, the Color-Aid always seemed to be lacking the color I wanted to use by some degree of hue, saturation or value, and I felt I wasn't able to complete the assignments with 100% accuracy...

In considering how you best learn, how would you rate these features in order of priority? - RGB vs CMYK color space

<table>
<thead>
<tr>
<th>Feature</th>
<th>Rating</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>1</td>
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<td>4</td>
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<tr>
<td>5</td>
<td>1</td>
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In considering how you best learn, how would you rate these features in order of priority? - Histogram

<table>
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<tr>
<th>Feature</th>
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<th>Percentage</th>
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<tbody>
<tr>
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<td>5</td>
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In considering how you best learn, how would you rate these features in order of priority? - Saved Color Selection Palette

<table>
<thead>
<tr>
<th>Feature</th>
<th>Rating</th>
<th>Percentage</th>
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<tbody>
<tr>
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<tr>
<td>5</td>
<td>4</td>
<td>40%</td>
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</tbody>
</table>
In considering how you best learn, how would you rate these features in order of priority? - Various ways to alter color

<table>
<thead>
<tr>
<th>Feature</th>
<th>Rating</th>
<th>Percentage</th>
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<tbody>
<tr>
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</table>

In considering how you best learn, how would you rate these features in order of priority? - Hidden Color Wheel

<table>
<thead>
<tr>
<th>Feature</th>
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<tr>
<td>5</td>
<td>1</td>
<td>10%</td>
</tr>
</tbody>
</table>

First and Last Name
Taylor Murphy      Katie Minser      Katherine Walker      Matt Shea      Andrew Bromwell      Victoria Billingsley      Ben Pappalardo      Lindsay Glover      Julia Miyake      Amelia Boyer

https://docs.google.com/spreadsheet/ccc?key=0AkhpoKNSGOW4dEwwe3hTn3zVCOWF13GDViUZ...
What is your intended profession upon graduation?
Cognitive Engineer  Theatre & Set Design  Usability Designer  Mobile & TV designer  Interactive/ Digital Designer  Identity & Brand Designer  Mobile Interface Designer  Visual Communication  ...  

How many hours a day will you be working professionally on the computer?
12  4  10  8  8  6  8  10  

How many of those hours will rely on accurate color contrast and color interaction on screen?
12  4  10  8  8  7  3  8  6  8  

Kinect Feedback - what are your feelings about this game being used in the classroom to teach students the RGB color wheel and about additive color mixing?
I think students will thrive using this application, especially once they learn the concept of additive color mixing. I think it would be able to show design students how to properly use the blend function in Photoshop, and how each different blend mode works. A fun, hands on learning exercise is always more exciting than a lecture with slides. I would like to maybe do this exercise early on in the course, facilitating good interaction among design students from various backgrounds, breaking the ice and building trust to gain positive feedback (and negative) during critiques throughout the re ...
<table>
<thead>
<tr>
<th>What is your intended profession upon graduation?</th>
<th>How many hours a day will you be working professionally on the computer?</th>
<th>How many of those hours will rely on accurate color contrast and color interaction on screen?</th>
<th>Considering how you like to learn, what are the strengths of this application?</th>
<th>Were the instructions easy to follow?</th>
<th>How did the interactions facilitate your understanding of the information?</th>
<th>After reflecting the use of this application, which particular area was most memorable?</th>
<th>Why was this function or area the most memorable?</th>
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</thead>
<tbody>
<tr>
<td>Cognitive Engineer</td>
<td>12</td>
<td>12</td>
<td>The simple interface is nice. The lack of clutter compared to other sites allowing experimentation of color helps me focus on the exercise at hand. I like how it is very similar to the current manner of learning about color interaction; through trial and error. This makes it an easier mental bridge from the physical activity to the digital activity.</td>
<td></td>
<td>By touching the screen and getting tactile feedback, it provides a richer environment and more degrees of freedom and choices. “Students could potentially get overwhelmed by the amount of choices and get frustrated.”</td>
<td>Two ways to desaturate a color. “This was never mentioned in my color theory course. Additionally, being able to see on screen a gradient with the degrees of change happening as I make changes made it very clear what is happening when I adjust the controls.”</td>
<td></td>
</tr>
<tr>
<td>What function resonated most with you? Why?</td>
<td>How does the experience compare to when you did this activity in Color 310?</td>
<td>Why do you prefer doing the activity that way?</td>
<td>In considering how you best learn, how would you rate these features in order of priority? [RGB vs CMYK color space]</td>
<td>In considering how you best learn, how would you rate these features in order of priority? [Histogram]</td>
<td>In considering how you best learn, how would you rate these features in order of priority? [Saved Color Selection Palette]</td>
<td>In considering how you best learn, how would you rate these features in order of priority? [Various ways to alter color]</td>
<td>In considering how you best learn, how would you rate these features in order of priority? [Hidden Color Wheel]</td>
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<tr>
<td>I don't have to worry about making mistakes; emphasis is on my selection of colors, rather than precision and measurements. This is also a reusable course, and my choices are readily able to recall, I can see the formula behind the scenes that created the contrast relationship between the colors I chose.</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Considering how you like to learn, what are the weaknesses this application?</td>
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<td>The 4 point circles that represent the color wheel could be bigger, so I know what exactly is happening behind the scenes. The central circular piece doesn't have a strong affordance, letting me know I can interact with it. Until I actually started playing with the app, I wasn't sure what it's function was. Even though I really like how much I can do with color in this environment, I doubt I will remember all of the functions of the various tabs without labels.</td>
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<td>Introductory tool tips that can be revealed and hidden based on user choice would be nice. I imagine after a few uses, I will no longer need the reminder. I would strongly suggest an in-class demonstration before giving the students free reign to use the application... possibly even an introductory video showing a student completing an entire exercise from beginning to end.</td>
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<td>I think students will thrive using this application, especially once they learn the concept of additive color mixing.</td>
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<td>Theatre &amp; Set Design</td>
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<td>I am easily able to navigate between the various ways of manipulating color and get immediate results instead of digging through random pieces of color-aid. This is also a cheaper option. I love the history, it would come in handy when explaining how I derived the final colors.</td>
<td>9</td>
<td>When you drag the larger piece, you see the color change right away. It is very clear what is happening to the color and why- due to the expanded panel on the right side of the screen.</td>
<td>The subtle hidden color wheel</td>
<td>Instead of seeing a giant color wheel, I see what I am focusing on, and can easily evaluate the contrast of the colors on screen without distraction. Too many colors on screen make me confused.</td>
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<td>How does the experience compare to when you did this activity in Color 310?</td>
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<td>In considering how you best learn, how would you rate these features in order of priority? [Hidden Color Wheel]</td>
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<td>The hidden color wheel was great- I hate trying to use an application with tons of visual clutter.</td>
<td>It is easier to see everything on one screen. Additionally, all of the colors I want to use are represented here, the Color-Aid always seemed to be lacking the color I wanted to use by some degree of hue, saturation or value, and I felt I wasn’t able to complete the assignments with 100% accuracy.</td>
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<td>None I can see right away.</td>
<td>I think it would be able to show design students how to properly use the blend function in Photoshop, and how each different blend mode works. A fun, hands on learning exercise is always more exciting than a lecture with slides. I would like to maybe do this exercise early on in the course, facilitating good interaction among design students from various backgrounds, breaking the ice and building trust to gain positive feedback (and negative) during critiques throughout the rest of the quarter. I would want this to be my first exposure to the RGB color wheel, especially since I learn best through trial and error.</td>
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<td>Usability Designer</td>
<td>10</td>
<td>10</td>
<td>I always prefer interactive learning to reading, lecture, slide shows, etc. I will give more of my attention to something that engages both my hands and my mind.</td>
<td>3</td>
<td>Being able to drag the wheel up and down when adjusting the tints, shades and tonal values of the color made sense. However, when adjusting the hue, I would show a behind the scenes transition of what is happening.</td>
<td>Histogram</td>
<td>The formula I used to create a color would be the strongest way for me to learn within this application. Especially since there are hour different ways to manipulate the colors (hue, saturation to neutral, saturation to complement, and value), Saving the colors is not a function I see myself using.</td>
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<td>Mobile &amp; TV designer</td>
<td>10</td>
<td>8</td>
<td>The interaction model is intuitive. I acknowledge the importance of color interaction and working with color on screen; everything I do with color in on screen and I often struggle with it.</td>
<td>8</td>
<td>It is always good to have some kind of tactile feedback, but the immediate visual feedback I receive in this application helped me understand immediately.</td>
<td>The subtle hidden color wheel</td>
<td>While it isn't a prominent feature, I would have fun exploring it to see everything it is capable of doing.</td>
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<td>10</td>
<td>Everything I do is digital now, I don’t even take notes with pencil and paper anymore. I am working on a night vision project that would benefit from me having taken this course.</td>
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<td>6</td>
<td>Using Color aid was too time consuming. That being said, I did enjoy using my hands and getting a little messy completing the assignments with physical materials. However, I never learned about color on screen.</td>
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<td>In the beginning I was trying too hard to learn how the application worked to focus on what was happening to the colors. While I appreciate you offering so many functions, it made it hard for me to keep up.</td>
<td>The mapping seemed off, especially once you rotated the color wheel, that should definitely be stationary.</td>
<td>This is a very interesting way to approach additive colors or how the RGB colors are created, interact and how the color space works in comparison to what we all know (red + yellow = orange, not the case in RGB)</td>
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<td>I would like to have an indicator somewhere on screen at all times - like which are of the application I am interacting with, so I know what I am doing and why.</td>
<td>Indicator or easy to hide tool tips.</td>
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<td>Interactive/ Digital Designer</td>
<td>8</td>
<td>8</td>
<td>The touch interaction is the strongest aspect. The ability to play on order to learn. Moving the main piece around is really cool. Additionally, a distinct separation of the 7 types of (Itten’s) contrasts would have been more effective than trial and error with Color-Aid paper. Real-time learning and the ability to rapidly make a million options is appealing to me. Especially the ability to see how some colors have a stronger or quicker effect on the relationship of the colors on screen is effective in learning.</td>
<td>8</td>
<td>Touch screen is always more effective for me.</td>
<td>Main menu of 7 different contrast exercises</td>
<td>When adjusting the hue- I would rather use the minimal 4 point color wheel with the suggested color wheel behind the scenes. I know what is between red and yellow (orange). The hue gradient strip on the side is what we always see in graphic software, and I feel like I always have to (click) a million times and still don't get the exact hue I am looking for. It is always too warm or too cool, especially when trying to find that perfect orange or violet. With the suggestive circular color wheel, I have a better mental model of exactly which direction to go in order to get the temperature of the hue exactly precise according to what I know about the</td>
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<th>In considering how you best learn, how would you rate these features in order of priority? [Hidden Color Wheel]</th>
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<td>This was so much quicker. I am a busy student, I want to get my projects done as soon as possible while doing them correctly and still learning. With this assignment (simultaneous contrast), I felt like I understood the concepts behind the exercises before I did the actual physical activity of creating an example. The actual creation of the activity felt mundane, tedious and unnecessary, I was ready to move on to the next color concept in the curriculum.</td>
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<td>I would make a demonstration part of the in-class lecture. Then once I get the idea, I would be anxious to jump in and start playing, especially once I realized it was an experimental approach rather than using the formula on the backside of the Color-Aid pieces. I would want to derive the formula myself, allowing me to learn on my own, I would remember that more easily in the future.</td>
<td>The constant gesture is unappealing to me. I would get tired of waving my hands around just to paint with red and green. I still like that I have the ability to just play. It would be interesting to use this device to demonstrate the actual difference between additive and subtractive color mixing. So the circle on one side is mixing the color additively and the other circle is using the subtractive approach. I am still controlling both sides rather than being distracted by what my opponent is doing.</td>
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<td>Function/Role</td>
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<td>screen is effective in learning.</td>
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<td>always more effective for me.</td>
<td>different contrast exercises</td>
<td>traditional color wheel.</td>
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<td>10 concept in the curriculum.</td>
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<td>[RGB vs CMYK color space]</td>
<td>[Histogram]</td>
<td>[Saved Color Selection Palette]</td>
<td>[Various ways to alter color]</td>
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<td>The placement of this aspect of the application easily lends itself as being the most important thing I focus on. Not only can I see the colors of the end points of the 4 point color wheel, but I know what is in between them. When I see the color actually shift on screen, it reinforces that concept in my head.</td>
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<td><strong>Color-Aid</strong> was a pain in the ass. My craft has always been my weakest trait as a designer, and without the poor craft my projects would have been stronger and my grade would have been higher. I also ran out of pretty colors quickly, and I was left with so much wasted paper at the end of the course that can not be recycled. This application eliminates all of these concerns.</td>
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<td>you like to learn, what are the weaknesses this application?</td>
<td>I would incorporate not just the actual gesture in order to apply &quot;paint&quot;, but the force with which you make the gesture could also affect the amount of paint I am applying. So if I wanted to create one of the tertiary colors, I could use less force to create a correct blend. Additionally, being able to learn the color wheel in an interactive setting, and why it works this way instead of the normal RYB Itten wheel makes more sense. It would stand out in my mind. Presenting the material to me and being told to just accept it doesn't resonate as memorable learning content, I need to know why and how, especially when learning about anything visual</td>
<td>I want to see labels at all times. It would still take me a few runs before I got the idea.</td>
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<td>There were several things to memorize, I am not sure I understood the concept of simultaneous contrast before we began the exercises. I would need more instruction on how to use the application, especially labels for each tab.</td>
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<td>Job Title</td>
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<td>Designer</td>
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<td>Mobile Interface Designer</td>
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<td>3 color</td>
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<td>these concerns.</td>
<td>I am torn on this question. I like them both. However this is free and Color-Aid was expensive for a first year college student on his own. I didn't like getting glue all over my hands, plus it smelled. My only hesitation is that I liked having a physical result I could take home as proof of that I learned, and I could show my friends and family what I did in class. I would also integrate a Pantone function into this application. Like the conversion of a Pantone color I am using to RGB pace or vice versa.</td>
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<tr>
<td>I would like to use this application to explore other aspects of color than just contrast, especially the temperature of a color. Maybe I can't tell the difference between warm and cool shades, but seeing them on screen next to each other would help me in my future design work. Like a warm black an a cool black (not true black) always look the same to me when viewing them in different environments, but them I put them on the same Photoshop document and don't understand why they don't match. I definitely want an UNDO button.</td>
<td>I would add an extra dot or two in reading sizes to show which direction the hue is heading in the 4-point color wheel, which might also eliminate the need to show a full color wheel. Either way, I need to see more than 4 colors, I don't know what is in between each of the colors all of the time. I also don't want to be given the ability to rotate the colors on the wheel, it should stay stationary, like red should always be at the top. I would add an undo button.</td>
<td>n/a</td>
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<tr>
<td>Visual Communication Designer</td>
<td>8</td>
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<tr>
<td>What function resonated most with you? Why?</td>
<td>How does the experience compare to when you did this activity in Color 310?</td>
<td>Why do you prefer doing the activity that way?</td>
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<tr>
<td>I would still want to do the exercise with Color-Aid too. I get sick of looking at a computer all day. That being said this offers someone like me an excellent balance between my physical and digital world.</td>
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<tr>
<td>Considering how you like to learn, what are the weaknesses this application?</td>
<td>How might you tailor the instructions to facilitate better comprehension of the concept?</td>
<td>Kinect Feedback - what are your feelings about this game being used in the classroom to teach students the RGB color wheel and about additive color mixing?</td>
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<tr>
<td>I don't see any right now.</td>
<td>I would add labels.</td>
<td>n/a</td>
</tr>
<tr>
<td>What is your intended profession upon graduation?</td>
<td>How many hours a day will you be working professionally on the computer?</td>
<td>How many of those hours will you rely on accurate color contrast and color interaction on screen?</td>
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<tr>
<td>Communications, New Media and Technology</td>
<td>8</td>
<td>6</td>
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<tr>
<td>I would still possibly first do the Color-Aid portion of the exercise. Then I would start playing with the touch screen. This application is very organized, as opposed to my physical desk in studio class. Everything is right in front of me and I can choose to expand an area to interact with it, then put it away when I am done. My work is what I am focused on, not clutter around it.</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>Considering how you like to learn, what are the weaknesses this application?</td>
<td>How might you tailor the instructions to facilitate better comprehension of the concept?</td>
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<tr>
<td>I don't like not being able to reference the full color wheel when I need it. Not the hue gradient on the side, the circular 12 point (ten wheel) we use in class. Beyond just adding labels, a beginner student will not know what H, S1, S2, and V represent. There should be definitions upon user request.</td>
<td>Label - I might not remember what each part did. Like I said, beyond just adding labels, what does it do? Why do I need to possibly use this function?</td>
<td>This would be so much fun, and I would have liked to have learned more about the RGB color space in class, since I will never be designing for print materials.</td>
</tr>
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<td>What is your intended profession upon graduation?</td>
<td>How many hours a day will you be working professionally on the computer?</td>
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<td>Mobile Application Management</td>
<td>10</td>
<td>8</td>
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<tr>
<td>1.  I liked having a physical piece to take home with me as proof of completion. I would make sure that was incorporated - similar to your older prototype, being able to reference past examples and comparing them to others in the class. Even though this project has a subjective result, I liked seeing what others came up with, and how they all compared.</td>
<td>7</td>
<td>3</td>
</tr>
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<td>Considering how you like to learn, what are the weaknesses this application?</td>
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<td>I don't understand the need for some of the functions, like RGB vs CMYK. I would simplify the nature of the application. It would be cool if there was tactile feedback, maybe even a shift in temperature. As I add orange, my fingers get a warming sensation. Or when it gets blue, my fingers feel colder.</td>
<td>I would add labels and tool tips or instructions that could be referenced when needed. If I remove a step from histogram, does that affect everything after that? What is the purpose of that function?</td>
<td>n/a</td>
</tr>
</tbody>
</table>
References Cited


http://www.swissnexsanfrancisco.org/Ourwork/events/colorandlight


http://www.realcolorwheel.com/othercolorwheel.htm


http://www.edutopia.org/technology-integration-introduction


