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THE USE OF GRAPHICS, ANIMATION AND INTERACTIVITY
IN A COMPUTER-BASED LESSON ON
LIGHT IN DIGITAL SPACE

by

Alexander P. Vance

A master's project submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirement for the degree of

Master of Science

Department of Instructional Psychology and Technology

Brigham Young University

April 2005

BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

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This project has been read by each member of the following graduate committee and by majority vote has been found to be satisfactory.

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As chair of the candidate's graduate committee, I have read the project of Alexander P. Vance in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable to fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

THE USE OF GRAPHICS, ANIMATION AND INTERACTIVITY IN A COMPUTER-BASED LESSON ON LIGHT IN DIGITAL SPACE

Alexander P. Vance

Department of Instructional Psychology and Technology

Master of Science

The following report discusses the design, development, and evaluation of a computer-based lesson treating the subject of how light is represented in digital space. The report contains an analysis of the need for the project, a description of the product itself, and the methods and results of the evaluation. It also contains a literature review that discusses the supporting research concerning instructional graphics, animation and interactivity, as well as instructional design in general.

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Sincere thanks are extended to my graduate committee: Dr. Paul Merrill, Dr. Stephanie Allen, and Dr. Stephen Yanchar. Their guidance in this field will doubtless follow me from campus. Special thanks is given to Dr. Larrie Gale, who provided me with an opportunity, and who served as the project sponsor and subject matter expert. His willingness to put this project in my hands is greatly appreciated.

A special thanks and appreciation to my wife, Jessica, for her understanding and her quiet “You can do it.” A greater collaborator does not exist.

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Purpose of the Project

Traditionally, the media arts division of the Theater and Media Arts Department (TMA) at Brigham Young University (BYU) focuses on the development and production of television and film, including the relative histories, theories, and aesthetics. Recently, however, an additional emphasis on interactive digital media, spearheaded by Dr. Larrie Gale, has been made available to students. This emphasis provides opportunities for TMA students, as well as those from other disciplines, such as education, computer science, and visual arts, to explore the tools, theories, and procedures involved in designing and developing interactive multimedia. Interest in this emphasis has slowly expanded over the past few years, as class enrollment increases and the course materials are continually refined.

The introductory course for the interactive multimedia track is *TMA 271: Multimedia Literacy*. The aims of the course are to provide “experiences designing and creating digital media used interactively, including exposure to production and authoring tools, and an orientation to the aesthetics, theory and history of interactive multimedia” (Gale, 2004, p. 2). Similar to other courses in the TMA department, it provides hands-on experience with production tools and concepts, while structured “around career goals and skills needed to solve problems to create digital, interactive media” (p. 2). Ideally, students should finish the course with knowledge and skills that will allow them to advance to other production-based courses, or to participate in internships.

Over the past few years Dr. Gale has tested a number of textbooks with his classes, only to find that each falls short in satisfying the needs of the course. Currently he conducts the course primarily from his own notes and lectures, providing the students

with supplementary materials from various sources. This deprives the students of a well-designed text that, as any instructor of an information-laden class can attest to, is an essential aid for the students. Ideally, such a text would give the students access to instruction outside of class, allowing them to set a pace for themselves instead of being constricted by the time allotted for the instructor. It would also allow them to better prepare for upcoming class discussions, as opposed to both presenting the information and attempting to discuss it all in the same class period. Such a text could also serve as a reference, allowing the students to return and review the material previously covered.

In an effort to create a tool that meets these requirements, Dr. Gale began work in the spring of 2004 with the Center for Instructional Design (CID) on the BYU campus, as well as with a few graduate students, in designing and developing a series of computer-based instructional lessons for his course. The author of this report is one of the graduate students invited to participate, with the assignment to design and develop the lesson treating the subject of light in digital space, or how light and images are represented in the digital domain. This instruction would be delivered by computer, and would help to fill the need presented by the lack of a proper class text.

The overarching objective for the *Light in Digital Space* (LIDS) lesson is to increase the students' conceptual knowledge of how computers use light and color, and to increase their ability to handle related multimedia production situations they would possibly encounter in the future. More detailed instructional objectives and specific learning outcomes were initially developed with the help of the stakeholders, and can be found in the Appendix A of this report. With these objectives in mind, the materials developed for this project include a computer-based lesson delivered on CD-ROM,

containing multiple modules and review questions; a questionnaire to receive feedback from end-users; and a pre-test and post-test for evaluation purposes.

Target Audience Analysis

The recipients of the instruction were university students that voluntarily register for the TMA 271 course, usually between the ages of 19 and 30. As an introductory course for a track within a major, it's likely that interest levels will vary. As determined by interviews with students enrolled in the class, some students approach the course certain that the material will serve as a foundation for the career they already aspire to in designing interactive multimedia. As the TMA department primarily attracts those interested in film or video production careers, other students treat the course as a curious exploration of what else exists in the realm of digital media, or as a resource to expand their skill set. As the students become familiar with the material, they will judge for themselves its perceived relevance to their intended career, and a corresponding level of motivation will follow.

Not unlike their motivational level, prior knowledge of the material varies from one student to the next. As an interdisciplinary collection of topics, some students bring knowledge gained from various sources, such as the principles of light in a physics class, or the nature of graphics from their own experiences with computers. For the majority of those participating, however, it is assumed that the module serves as an introduction to the principles of light in digital space. It is also assumed that all students are familiar with and have previously used computer-based instruction.

Literature Review

Existing Instructional Materials Search

The end purpose of this project was very practical: to develop a product that could be used effectively as part of the course curriculum. After understanding the needs of the stakeholders and defining the target audience, it was necessary to research current possible solutions that could be used in lieu of developing an entirely new product. In evaluating these products, the stakeholders determined several criteria that an acceptable solution would contain: (a) the product should be standalone instruction that can fill the traditional role of a take-home textbook; (b) the product should provide content on how light is represented in digital space; (c) the product should encourage practical application of the content in production situations, through examples, questions, and so on; and (d) the product should be appropriate for the audience and an introductory course. After weighing the advantages and disadvantages of various instructional media, it was later decided that computer-based graphics, animation and interactivity would be required elements for the product. A fifth criterion was therefore added to the list: (e) the product utilizes computer-based graphics, animation and interactivity. The following paragraphs describe products that are representative of those reviewed.

Textbooks and other published works comprised the majority of potential solutions. By nature, most of the textbooks could serve as standalone instruction, though few of them addressed the required information, and none of them, of course, contained animated elements. For example, *How Multimedia Works* (Holsinger, 1994) targets the appropriate entry-level audience, focusing on the basics of what makes up computer-based multimedia. Graphics are plentiful and are used effectively to communicate the

bulk of the information. Due to the nature of the information, however, much of which is chronological or cause-and-effect, it's possible that animation would be an even more effective presentation method (Rieber, 1991). The contents are also much broader than they are deep, and there is no effort to facilitate a practical application of them.

Fred Hofstetter's *Multimedia Literacy* (1996) has been used by Dr. Gale in previous semesters of his TMA 271 course. Its use was discontinued, however, because the focus of the lengthy text is on the contemporary tools and practical applications of multimedia as opposed to the science or "nuts and bolts" behind it. The text contains an effective use of graphics and charts, and some practical application is provided through questions and suggested assignments in each chapter.

Multimedia in Practice (Jeffcoate, 1995) is typical of the "all-in-one" book that contains information on many aspects of multimedia, from tools to applications to the science behind it. While there is depth as well as breadth to the information, only part of it is applicable to the TMA 271 course curriculum. More importantly, there is almost no use of graphics in the text, which denies the user a potentially powerful learning tool.

One would think that instructors of multimedia production would encourage the integration of multimedia-based instruction into their curriculum – using the medium to teach the medium. No computer-based products were found, however, that met the necessary criteria. An excellent example that demonstrates how technology can be used to teach technology is *Zettl's Video Lab* (2002). This computer-based product instructs the user in the basics of video production through examples, interactive simulations, and explanatory video and animation. The interactive nature of it provides experience in situations that, if physically carried out, would require a great deal of equipment and set-

up time. While not a standalone product, as it's accompanied by a textbook and workbook, it contains a substantial amount of material.

This review did not encounter any computer-based product addressing multimedia production that approached the complexity of *Zettl's*. Some website elements, such as those found at the Rochester Institute of Technology website (Johnson, 2001), provide interactive Java applets that allow data to be manipulated, in this case the gamut of the chromaticity diagram. The elements are generally modules designed to be accessed by students of a particular class, and do not function as standalone instruction.

Review of Instructional Design Theories

Instructional design theories are those ideas that serve as guidelines for designing and developing instruction. For this project, two models were used in creating the LIDS lesson, both of which are considered standards in the field of instructional design. For the process of creating the instruction, Dick and Carey's (2000) well-known *systems approach model* was followed. For the design of the instruction, Gagné's (1979) equally renowned *events of instruction* was used.

The Instructional Design and Development Process

The systems approach model views instruction as a "systematic process in which every component...is crucial to successful learning" (Dick, Carey, & Carey, 2000, p. 2). The model suggests a series of cohesive components designed to guide the design and development of instruction. These components include the following: (a) assess needs to identify goals, (b) conduct an instructional analysis, (c) analyze learners and contexts, (d) write performance objectives, (e) develop assessment instruments, (f) develop an instructional strategy, (g) develop the instructional materials, (h) design and conduct the

formative evaluation, and (i) revise instruction. These components were used in this project as suggested by the authors, with a few modifications to match the resources and needs of the project, as described in the following paragraphs.

The design and development of the LIDS lesson began when the sponsor, Dr. Gale, recognized the need for such materials in his class. He recruited the assistance of the designer, who conducted a needs analysis and a task analysis. These were achieved largely through interviews with the sponsor, as well as discussions with former TMA 271 students and a subject matter expert that currently works in multimedia production. These analyses allowed the designer to identify the instructional goal of creating a module that helps students gain an understanding of the principles of light in digital space, and encourages the application of them in practical situations (component one of the systems approach model). An instructional analysis followed (component two), which primarily identified what entry-level behaviors were required of the learners to successfully begin the instruction (Dick, Carey, & Carey, 2000). It was determined that, due to the varied backgrounds of students that enroll in the class, the only entry-level behaviors that could be expected were an interest in the subject matter and a basic knowledge of computer use, since the initial concept was to create a computer-based lesson. As a lesson in an introductory course, these behaviors were sufficient for designing the instruction. This same analysis allowed the designer to conduct an analysis of the target audience (component three), which has been discussed previously.

After the various analyses were completed, performance objectives were created (component four). To accomplish this, general instructional objectives (GIOs) were determined that provided general behaviors the learners should accomplish. Each GIO

also contained specific learning outcomes (SLOs) that listed specific tasks that the learner should be able to complete. The concept of GIOs and SLOs was taken from the work of Gronlund (Linn & Gronlund, 2000). A complete list of the GIOs and SLOs for the LIDS lesson can be found in Appendix A. From the instructional objectives, the assessment instruments were developed (component five), including the pre/posttest, and the questionnaire used in the small group test. The advantage of creating the instruments early in the development process was the ability to refine them during the clinical evaluation sessions.

While Dick, Carey, and Carey list the development of the instructional strategy as a single step in the model (component six), creating and refining the strategy was a continual process from the beginning of the project. Dr. Gale requested at the outset that the lesson be computer-based, in part so that the students could see examples of multimedia within the instruction itself (i.e., teaching technology with technology). Due to the highly visual nature of the material, the designer proposed that the lesson rely heavily on graphics and animation. And with the need for the students to practice and apply what they learn with practical situations, Gagné's instructional model was chosen as the primary outline.

As discussed previously, the existing material that could satisfy the instructional objectives was scarce, and therefore all of the materials were developed from the ground up (component seven), utilizing the selected instructional strategy. This development occurred hand-in-hand with the formative evaluation of the materials (component eight), using prototypes and the evaluation process described later in this report. This evaluation was part of a cycle that also contained the ninth component, revising the instruction.

Principles of Instructional Design

Gagné's *events of instruction* (1979) have been implemented by instructional designers for decades, and were similarly referred to in designing the LIDS lesson. These nine events are “designed to make it possible for a learner to proceed from ‘where he is’ to the achievement of the capability identified as the target objective” (Gagné, 1979, p. 155). These events, presented in a probable order, though not a necessary order, are (a) gaining attention, (b) informing the learner of the objective, (c) stimulating recall of prerequisite learnings, (d) presenting the stimulus material, (e) providing learning guidance, (f) eliciting the performance, (g) providing feedback about the performance, (h) assessing the performance, and (i) enhancing retention and transfer. The LIDS lesson follows these events closely, although Gagné noted that “by no means are all of these events provided for every lesson” (p. 157).

Gaining the attention of the learner is accomplished through a variety of events, from a carefully planned question to the use of fast-paced media. The event should be tailored to the audience and their interests (Gagné, 1979). In the LIDS lesson animation, graphics, and audio narration are used as content delivery methods, but certainly act as attention-getting devices, as well. One of the advantages of dynamic animation is its ability to gain and regain attention throughout the learning experience (Rieber, 1990).

The second event involves informing the learner of the objectives of the instruction, or what kind of performance will be used as an indicator that learning has occurred (Gagné, 1979). This focuses the efforts of the learner and prepares them for the performance assessment. The third event is to aid in the recall of previously learned

abilities that will apply to the forthcoming stimulus material. This can be done through a series of recall questions, or even a review of the material previously presented. While the actual prerequisite capabilities for the LIDS lesson are few and simple, the first few modules review some basic principles that are necessary to understand the subsequent modules. These can serve as either stimulus material or, for those that are already familiar with the principles, a stimulus for recalling prerequisite information.

With these conditions set, the stimulus materials can be effectively presented. This is followed, or often paralleled, with the fifth event, providing learning guidance (Gagné, 1979). This event provides questions or other communication that aid the learner in understanding the material, which ultimately “contributes to the efficiency of learning” (Gagné, 1979, p. 161). The LIDS lesson facilitates this step through intermittent questions, as well as review questions at the end of each module.

These end-of-module questions also serve to implement the sixth step, eliciting performance. Of this event, Gagné (1979) suggests that there is a need to inform the instructor that learning is occurring, but also to inform the learner that they are indeed “getting it”. Ideally this performance is closely followed by feedback, the seventh event, informing the learner of the correctness of their performance. The performance also requires an assessment (event eight), raising the “questions of reliability and validity” (Gagné, 1979, p. 163). This event encourages the instructor to evaluate the performance, determining if the student actually understands the material. While assessment materials were developed for evaluation purposes in this project, those materials are not actually part of the instruction. Further assessment concerning this step is encouraged, but left to the administrator of the lesson.

The ninth event enhances the student's retention and transfer of the material (Gagné, 1979). This includes various activities that play on the meaningful context the material was learned in and the "network of relationships" (p.164) associated with the material. In this lesson, those activities include questions that topically link information from various modules, and interactive simulations that pull concepts from several different points in the lesson. The "Product Description" section of this report further demonstrates how the LIDS lesson utilizes these steps.

Review of Theories Related to Computer-Based Instruction

It was decided by the designers early in the design process that the end product should consist of computer-based instruction (CBI). The visual nature of the material and the cause-and-effect situations found therein seemed to lend themselves to the unique elements that CBI can provide. The argument of the effectiveness of CBI compared to traditional methods of instruction has been lengthy and inconclusive over the past few decades (Clark & Mayer, 2003; Morrison, 2001; Rieber, 1992). However, one aspect of the argument garners unanimous agreement: CBI that is poorly or ignorantly designed does more to hinder learning than facilitate it (Clark & Mayer, 2003; Rieber, 1994; Schwier & Misanchuk, 1993). This is especially true in the use of media elements in CBI, which are often included simply because of their user appeal (Rieber, 1994), or even their appeal to the designer.

The following paragraphs discuss a few of the major theories on how to effectively implement the unique abilities of CBI. Many of these ideas were utilized in designing the LIDS lesson, and focus particularly on the graphics, animation, audio and

interactive elements. For more detail on the implementation of these principles in the LIDS lesson, see the “Product Description” section in this report.

Graphics, Animation and Audio

Graphics. For the purpose of this discussion, a *graphic* is defined as “the display of nonverbal information” that visually represents an actual person, place or thing (Rieber, 1994, p. 3). Graphics have long found a place in instructional materials as a whole and computer-based instruction specifically (Tversky, 1995). Much of the support for using graphics and animation in CBI stems from Paivio’s dual-coding theory, proposing that two separate systems exist for processing information – one for verbal information (spoken or read) and the other for visual (Clark & Paivio, 1991; Mayer & Anderson, 1992; Rieber, 1991). Dual-coding research suggests that pictures are easier to remember than words, and information processed using both systems is easier to remember than information processed in any single system (Presno, 1997). When both systems are used, a referential connection is created between the verbal representation and the visual representation, which enhances retention and, as some suggest, enhances transfer problem solving (Mayer & Sims, 1994).

Clark and Mayer (2003) suggest two principles to follow when using graphics in CBI. Based on empirical evidence conducted primarily by Mayer and his colleagues, the *multimedia principle* parallels the conclusions of the dual-coding theory, in suggesting that neither graphics nor words should be used exclusively, but should be used together to engage the user in active learning. It’s important that the graphic be an explanative illustration that helps the user to learn the material, and not merely a decorative

illustration. The basic structure of the LIDS lesson follows this principle, utilizing graphics and animation accompanied by voice-over narration.

Upon using both graphics and text together, the application of the *contiguity principle* is encouraged (Clark & Mayer, 2003). This suggests that text and the corresponding graphics should physically appear together in the same time and space in order to facilitate creating a connection between the two elements. This includes situations such as placing feedback on the same screen as the corresponding question, as in the review questions of each of the LIDS modules.

Animation. Many of the same principles suggested for graphics apply to animation. Since its introduction, the use of animation in CBI has performed two basic purposes: to aid the presentation of information, and to serve as an extrinsic motivator (Rieber & Hannafin, 1988). Instructional animation has continued to evolve with the advances in computer technology, and still remains an effective tool for instruction (Mayer, 2001). It also still serves as an extrinsic motivator, though perhaps now to a lesser degree due to the abundance of animation students are exposed to through the internet, computer games, and etcetera.

Rieber states that animation is “the external visualization of an idea over time moving in a certain direction” (1991, p. 318). This definition suggests several elements that bring animation to a different plane than static graphics: learning can be aided by animation if the task requires visualization of a concept over time (e.g., the erosion of soil), or in a particular direction (e.g., the path of the moon around the earth). In addition, animation can potentially help a user visualize a dynamic process that would be

impossible for them to visualize on their own, such as the behavior of ocean wave dynamics, or the path of reflected light entering the eye (Rieber, 1991; Whitford, 2002).

Drawing from a number of the foundational studies examining the effectiveness of instructional animation, Rieber (1990) suggested three characteristics that the animation must include for it to be an effective tool. The animation must (a) be consistent with the learning task, (b) illustrate concepts that are difficult for the learner to visualize on his/her own, and (c) serve as both an attention-getting device and a presenter of content.

Audio. Important to this project is the relationship of the visual graphics and animation to the information presented verbally. Mayer (2001) aptly points out that what is often considered *multimedia* instruction is more appropriately, with the dual-coding theory in mind, *multimodal* instruction, since the presentation media matter less than the number of senses receiving it. A common error in CBI is the combining of both animation and crucial text on the screen at the same time (Clark & Mayer, 2003). The attempt to focus on both elements simultaneously overloads the visual channel, making it less effective than presenting the text through an aural narration. Exceptions to this rule include text that appears unaccompanied by graphics, such as the presentation of steps to a procedure, or brief text that integrates with the graphics, such as labels or new vocabulary.

Empirical evidence also shows that presenting the audio information in a conversational manner increases recall and transfer compared to a formal audio presentation (Mayer, Sabko, & Mautone, 2003; Moreno & Mayer, 2000). A more personal narration style can be achieved by using first- and second-person pronouns, and

framing the narration as though in a casual conversation. The result is a user that puts more effort into understanding what is being said (Clark & Mayer, 2003).

Interactivity

While the effectiveness of computer-based instruction compared to traditional instruction has been a continually debated topic, it has long been accepted that ‘learning by doing’ engages the learner and potentially provides a more effective learning situation (Brookfield, 1986; Cairncross & Mannion, 2001; Lewin, 1951). In fact, Schwier and Misanchuk suggest that “the potential of any instructional medium is only realized in a highly interactive mode” (1993, p. 6). When it comes to instructional multimedia, Evans and Sabry (2003) suggest a simple three-way model of interactivity, which requires initiation (on the part of the computer), response (from the user), and feedback (again from the computer). This model encapsulates all types of interactivity, from simple navigational options, to quiz questions, to complex interactive simulations.

The most basic form of interactivity in CBI is providing the user with control over the pace of the experience. Giving the users simple options to play, stop, or pause the presentation, or stopping the presentation periodically and then giving them those options, reduces the cognitive load on their working memory and allows them the opportunity to build a coherent mental model (Mayer & Chandler, 2001; Rieber, 1994). In that same vein, providing the users with navigational control allows them a non-linear freedom to concentrate on items they are unfamiliar with or interested in (Cairncross & Mannion, 2001). Often a “semi-linear” freedom is suggested, providing a linear structure with non-linear access, in order to allow arguments to build progressively over sections

but still giving access for review or exploration (Leeder, 2000). This was the structure that was primarily used in the LIDS lesson.

More complex interactive elements “should actively engage the user in carrying out tasks, which allow them to apply the new knowledge being presented” (Cairncross & Mannion, 2001, p. 161). Such elements include online quizzes or self-reflection questions, which provide the user instant feedback; simulations, in which a user is given a life-like situation and allowed to manipulate elements to see the results; and games, where the user’s new knowledge is utilized in engaging and inventive ways. Ultimately, activities should cause the user to “think about the material that is presented, what it means, its relevance, how it can be applied and in what contexts” (Cairncross & Mannion, 2001, p. 161).

Product Description

Production Tools and Delivery Formats

The LIDS lesson was developed primarily in Macromedia Flash MX 2004, with individual elements created in Adobe Illustrator, Photoshop and After Effects. Flash MX 2004 was the ideal production application due to its ability to deal with graphics and simple animation, and for its scripting abilities that allowed the design of interactive elements. The lesson was broken into individual modules, as described below, which were exported as Flash Shockwave Files (SWF). These SWFs were then embedded in HTML files for easy access using a web browser. A version detector was also embedded in the initial file to detect whether or not the computer has the correct version of the Flash Player installed.

Early in the design phase, the question arose as to the delivery method that would be used for the lesson, whether delivered from a web server or distributed on a CD or some other format. A large part of the rationale behind using Flash as the primary development tool was its availability and ease of use, but also considered was its ability to develop vector-based animation that results in small, web-deliverable files. There was a concern, however, that the media-rich designs would still make the files too big for web access. The decision was made to place priority on the effective use of animation and graphics, and the size of the resulting SWF files would determine the delivery format. The final SWF files were too large to be accessible from all types of internet connections, and the decision was made to deliver the product on CD, which also allows for offline access by the user.

LIDS Lesson Structure

The LIDS lesson is comprised of seven distinct modules whose semi-linear content was derived from the original outline provided by the sponsor. Each module utilizes an off-screen narration supplied by a female voice that speaks in a conversational manner (Clark & Mayer, 2003). Animation and graphics are employed in each module, and all but the first and last modules contain interactive elements designed to engage the learner and further their understanding of the material. The modules use the following descriptive titles and are presented in this order: *Introduction*, *Light & Color*, *Eyes & Color*, *Bits & Pixels*, *Bit Depth*, *Color Models*, and *CODECs*. In addition, an orientation segment is inserted at the beginning of the lesson to explain the navigational options, and a brief review of the entire lesson is provided at the end to facilitate retention and transfer.

Module Navigation

The LIDS lesson is primarily designed to be experienced linearly; the first four modules each build on those preceding them, while the final three modules are independent of one another, but still draw from the information presented in the first four. This linear presentation is automated, but pauses at the end of each module subsection to force the user to slow down and process the information presented, providing a more conscious sense of control over the pacing (Mayer & Chandler, 2001). The top of the visual display contains a list of the module titles in a simple timeline (see Figure 1). These are accompanied by a ball that moves from one title to the next as an indicator of the user's location within the lesson. These titles also serve as links that the user can choose at any point during the lesson, providing non-linear access to each module for review.



Figure 1. Screen shot of the lesson navigation bar – located at the top of the interface.

The bottom right corner of the visual display provides additional navigational options (see Figure 2). The Previous and Forward buttons allow the user to jump to subsections of each module, permitting more immediate access to specific parts of the content. When the linear presentation pauses at the end of a subsection, the Forward button changes from blue to green as an indication that it's waiting for the user's response before continuing. A Pause button is also available, again providing the user control over the pace of the experience.



Figure 2. Screen shot of the extra content option button (left) and navigation buttons (right).

Extra Content Options

The bottom left side of the display area, also displayed in Figure 2, contains three boxes that are provided to give the user occasional insights into information related to the content, but not necessarily discussed during the lesson. When an extra content option is available, the word or phrase of the content appears in the box, and the user can click on it to gain access to a screen containing the relevant information (see Figure 3). The option remains available throughout the subsection, such that if the user doesn't wish to pause the lesson to see the content, they still have that option when the end-of-subsection pause occurs. The extra content consists of information that is assumed to be review for the user, or that is relevant but simply doesn't have a place in the main discussion.

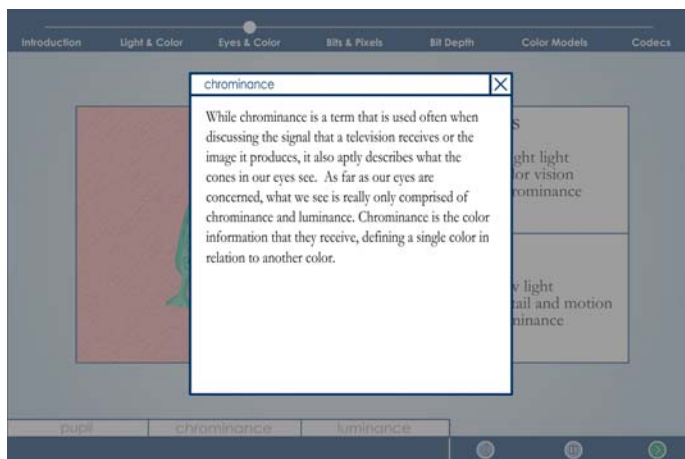


Figure 3. Screen shot of an example of an extra content option.

During the *Light and Color* module, for example, the electromagnetic spectrum is mentioned in discussing visible color. It is assumed that the user is at least familiar with the electromagnetic spectrum, but if not, it won't detract from their understanding of the main concepts presented. Those that are interested in learning more about it, however, can take advantage of the extra content option. The text of the extra content options is included in Appendix B.

Module Review Questions

At the conclusion of each module the user is given the opportunity to complete a series of review questions, averaging six questions per module. The questions take the form of multiple choice and written response, and address the following objectives: (a) allow the user the opportunity to self-assess their understanding of the principles discussed; (b) encourage the user to think about how the principles discussed could apply to “real-life” situations; and (c) encourage the users to think about how the principles discussed in the module relate to those already discussed, or those yet to come.

The structure of the multiple choice items was designed according to the suggestions given by Linn and Gronlund (2000), whose instructor assessment structure still seemed appropriate for the self-assessment nature of the questions. When the user chooses the correct answer, a brief response is provided as to why it is correct. When a wrong answer is chosen, a response is given explaining why it is incorrect, and then explains the correct answer. The written response questions require the user to explain a concept or respond to a given situation. The user is provided a text box to type their answer, and upon clicking the Submit button, a sample answer is shown that can be used as a comparison (see Figure 4). The answers to both types of questions always appear on the same screen as the question, allowing the user to compare the two (Clark & Mayer, 2003). As these are obviously not questions intended to evaluate the student’s competency, they require motivation on the part of the student to complete them. In working with test audiences, however, they frequently commented that both types of questions were very valuable in assuring them that they understood the concepts.

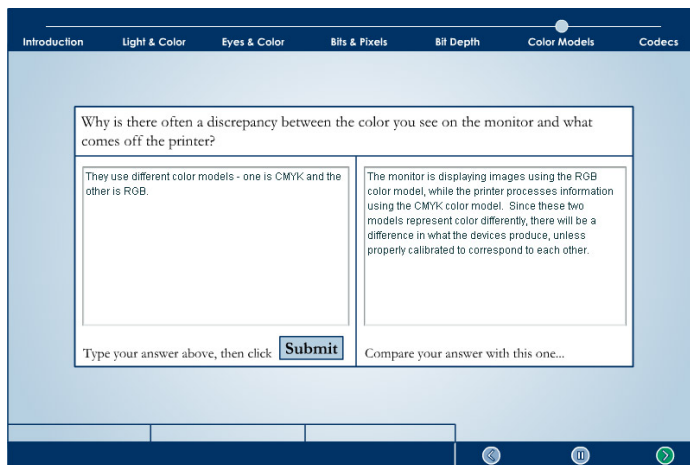


Figure 4. Screen shot of a sample written response module review question.

LIDS Lesson Modules

Each of the modules in the LIDS lesson is presented in the same display area, with the navigational framework mentioned above. A brief description of each module is provided here to demonstrate how the principles of instructional design, graphics, animation and interactivity as discussed previously are implemented. A full multimedia production script can be found in Appendix C.

Module One: Introduction

The first module begins with an orientation provided by the narrator, and accompanied by arrows pointing to the areas on the screen that are referenced. This direction is primarily given to alert the user to the navigational options they have during the lesson, and is reinforced by presenting the information on the same screen that will accompany them throughout their experience (Clark & Mayer, 2003). From the beginning of this module and throughout the lesson, the narrator speaks in a relatively conversational tone with the user. While it was decided not to embody the narrator in a visual character or agent, the casual manner of presentation aids in the effort to engage the learner (Clark & Mayer).

The next section of the *Introduction* module is designed to (a) gain the attention of the user, and (b) explain the purpose of the lesson and introduce the modules that are forthcoming. The attention-getting activity is composed of simple animation accompanied by sound and music, and also serves as a motivator in explaining the need for the information the user will be studying. The introduction of the modules that the student will experience creates a visual connection with the titles at the top of the display, to reinforce those titles as both a reference and as buttons to access the individual modules (see Figure 5).

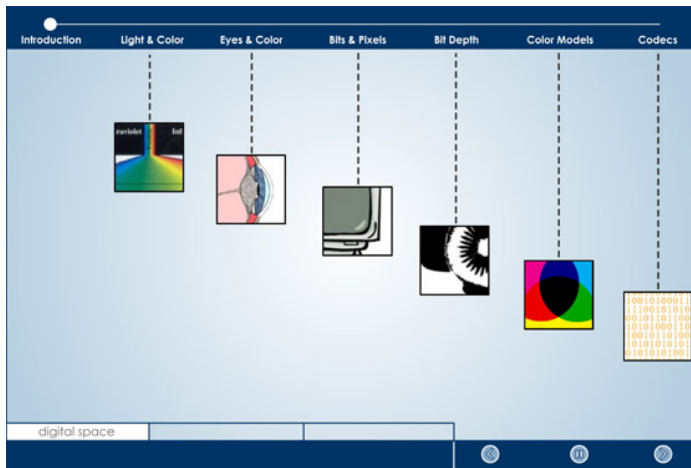


Figure 5. Screen shot of the introduction to the module topics.

Module Two: Light and Color

In early discussions with the sponsor and the subject-matter expert it was decided, based on their classroom experience, that the students would require some review of basic principles of light, color, and even computer bits. While the majority of students would have encountered these subjects somewhere during their scholastic careers, for most a review would be necessary in order to better understand the production-specific concepts that were to be discussed. Additionally, making a direct connection between subjects such as the human perception of light and the use of CODECs would motivate

the student to retain the knowledge of the more abstract subject, and encourage transfer of it to other topics not discussed in the lesson, such as using tools in Photoshop.

Light and Color addresses the most basic topics presented in the LIDS lesson: the wave-like nature of light, the visible light spectrum (color), and additive and subtractive color. Graphics and animation were especially useful in distinguishing between additive and subtractive color. At the most basic level, examples of items that use the two forms of color were presented as graphical representations, allowing the user to associate a visual image of an object with the type of color it utilized. Important to the student's understanding of additive color is the use of red, green and blue as primary colors that can combine to construct virtually any other color. This concept is introduced using an animated set of color circles that intersect, causing the colors to blend and allowing the user to see the "before and after" appearances as the circles move. This is then reinforced by using the additive example of colored flashlights shining on a wall, and the user can turn the flashlights on and off to see the results (see Figure 6).

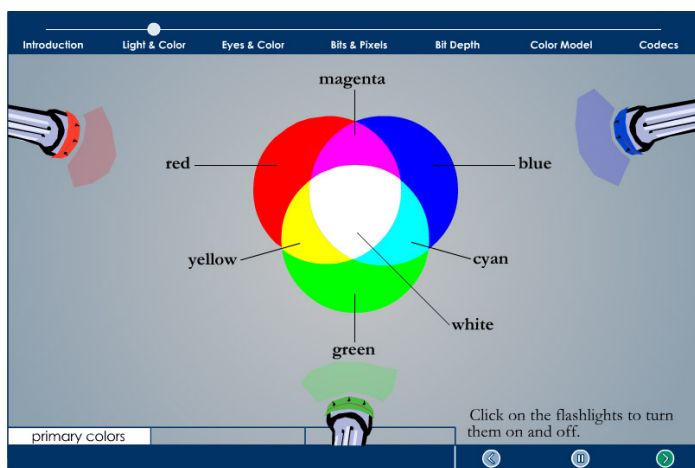


Figure 6. Screen shot of the flashlight activity in Module Two.

The module review questions for Module Two differ from others in the lesson, due to the fact that the nature of light and color is not directly applicable to a multimedia

production situation. The questions, therefore, focus on the concepts themselves, and more abstract situations, such as the theater lighting questions, that students probably wouldn't encounter on their own, but that still allow them to consider the science in a recognizable setting.

Module Three: Eyes and Color

Similar to *Light and Color* in its foundational nature, *Eyes and Color* discusses the capabilities of rods and cones in the human eye, the limitations inherent in them, and how they are represented on the chromaticity diagram. As a dynamic process that moves from one set of variables to another, explaining how the rods and cones of the eye allow human perception of light and color would be difficult to accomplish with simple text or even a still graphic. With elements of motion, trajectory, and process, however, it conforms well to the use of animation as a delivery method (Rieber, 1991).

The cause and effect relationship of light, color and human perception also provide an opportunity for the user to experiment with that relationship in a simulation activity found in Module Three. The concept uses the idea that in low light, the sensitivity of the rods allows them to function, but the cones require bright light to function. Since rods control the detail we see and cones control color, the result in dim light is an ability to see details but not colors. To demonstrate this, the user is provided with a slider that controls the amount of light in the virtual room. When the light is at full strength, the colors appear vivid, but as the light decreases, the colors become muted and gray. This activity provides the user immediate feedback to their actions related to the principle demonstrated (Clark & Mayer, 2003).

The review questions of Module Three also contain a type of question that is not used elsewhere in the lesson. The final question asks “Our eyes are amazing instruments, but they do have limitations. Why might these limitations be important in creating digital media?” It is not expected that the user will be able to provide all, or even some, of the reasons given in the model response. But these limitations are central to the concepts of bit depth and CODECs (as presented in modules five and seven), and even if the student replies “I don’t know,” and simply goes on to read the model response, their thoughts have been turned to how these basic principles can apply to the more specific and complex principles that will soon be introduced.

Module Four: Bits and Pixels

As the first two content modules discuss the nature of vision, module four looks at the other side of the digital representation equation: the storage and presentation of information in a computer. The most important concept conveyed in this module is the function of a bit. An animated chart is used to effectively display how bits can combine to create complex patterns, a concept that is referenced several times in subsequent modules (see Figure 7). This module is brief and primarily serves the purpose of setting a foundation for the concepts in Module Five. There are no interactive elements in this module, aside from the review questions, as the designer was unable to create an activity that would facilitate understanding of the principles beyond what the animations achieved.

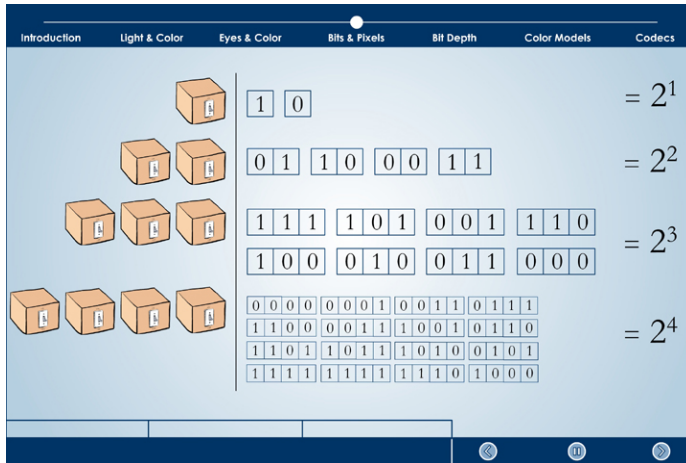


Figure 7. Screen shot of the bit diagram in Module Four.

Module Five: Bit Depth

Module Five is the first module that moves beyond the foundational concepts and introduces material that will have a more direct application to the decisions a student would make in a production situation. It discusses the concept of bit depth in visual representations, and how computers can alter bit depth to change the relationship between file size and image quality.

The module begins with a quick series of questions for the user aimed at reviewing the concept of additive light. This brings to mind principles from Module Two that are central to the understanding of bit depth. The additive nature of pixels is then discussed, and the user is presented with a cause and effect animation that demonstrates the relationship between the brightness of the pixel phosphors and the resulting color of the pixel.

The main purpose of discussing bit depth is to help the student understand how it can be manipulated to change the visual quality of an image or to change the file size. The visual nature of this cause-and-effect relationship lends itself well to animated and interactive elements. The user, for example, has an opportunity to view a single photo

and manipulate its bit depth to see the perceptible change, or lack thereof (see Figure 8). The color palette used in each bit depth is also shown, providing the user a visual reference of what it means, for example, to use “256 colors”. In discussing 24-bit color, the user has an opportunity to manipulate the value of each channel, or pixel phosphor, and see the immediate results as the given picture changes color accordingly (see Figure 9). This emphasizes the tri-channel nature of 24-bit color, and the levels of variation each channel is capable of.

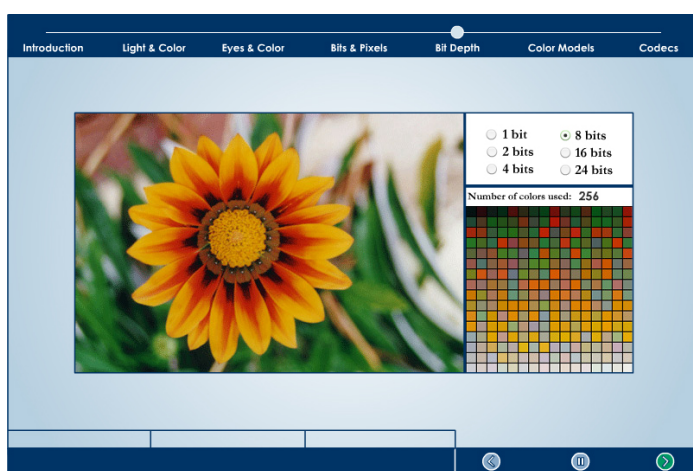


Figure 8. Screen shot of the bit depth activity in Module Five.

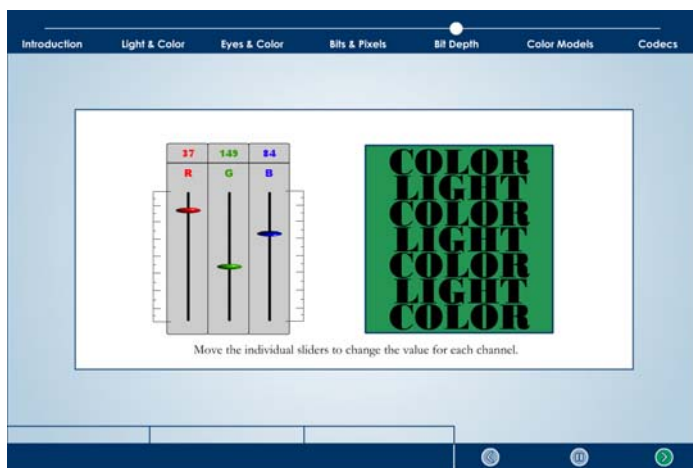


Figure 9. Screen shot of the 24-bit color channel activity in Module Five.

Another unique animation presented in module five is intended to reinforce the relationship between image quality, file size and internet download time. The animation features a graphic that gradually increases in image quality (with an implied increase in bit depth), and displays the corresponding increase in file size and download time (see Figure 10).

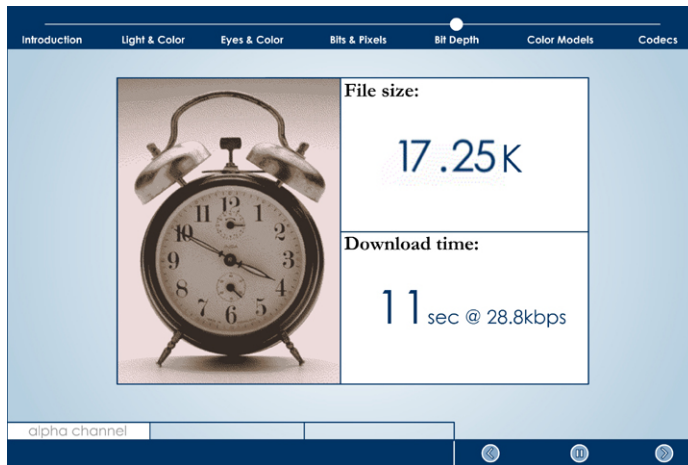


Figure 10. Screen shot of the quality/file size/download time animation in Module Five.

Module Six: Color Models

The challenge in designing and presenting Module Six is the complex nature of the topic. Color models are abstract concepts that require delving into their mathematical roots in order to really understand how they function. In creating this module, the designer decided to develop a metaphor for understanding the basic idea of color models, and then discuss their direct application to digital media production.

The somewhat playful metaphor chosen was a decoder ring, which receives a short series of numbers, accompanied by the type of color model, and produces the appropriate color. Though metaphorical, the idea was still aided by a cause and effect animation. Color models were further explored by dissecting the channels of an image using a particular color model. Similar to the bit depth exercise of Module Five, the user

is presented an image, and allowed to turn each color channel on and off to see how they interact in producing the final image (see Figure 11).

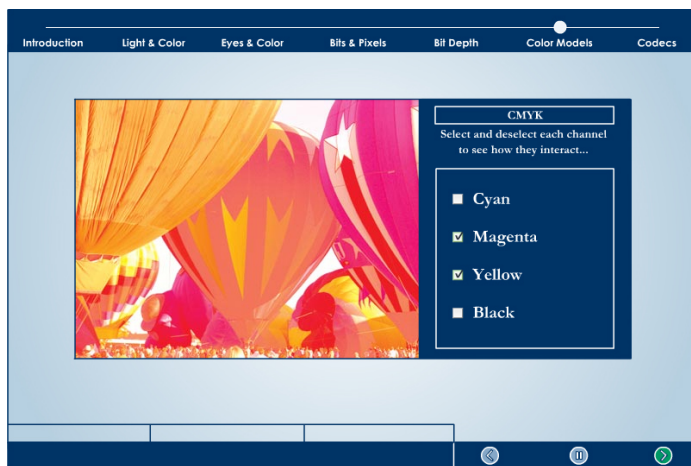


Figure 11. Screen shot of the CMYK layers activity in Module Six.

Module Seven: CODECs

In explaining another abstract concept, module seven subscribes to a similar pattern as the *Color Model* module, in choosing an animated metaphor to explain the process. This module discusses how computers use compression algorithms to store and transfer information more efficiently. It then focuses on the use of compression CODECs in developing audio, still images, and video for multimedia production. The metaphor of a novel is used, demonstrating how “compressing” a sentence of the novel can reduce the amount of information required without reducing the utility of the information. This multi-step metaphor is aided by the use of animation, in allowing the user to better follow the process.

The *CODECs* module deals with media elements that will be viewed on a computer. The opportunity to discover this principle as CBI is therefore important, since there are subtle differences in the graphics as they appear on the computer monitor that may not look the same when simulated on a printed page. This shows one of the primary

advantages of using digital media to teach about digital media – there is no need to simulate or represent the digital examples in another medium.

Module Eight: Review

Module Eight is not accessible from the timeline navigation, and only occurs automatically after the user has completed module seven. The purpose of the review at this point is to simply show the user a high-level view of what they have experienced. It briefly mentions the main points of each module, with accompanying graphics that help to stimulate recall of that principle. This recap should aid the user in connecting the principles that were first introduced with those they just finished, aiding in recall and transfer of the information (Gagné, 1979).

Evaluation

Gagné and many other instructional design theorists avidly propose that evaluation is a necessary element of instructional design (1979; Paas & Firssova, 2004). Fitzpatrick, Sanders and Worthen define evaluation as “the identification, clarification, and application of defensible criteria to determine an evaluation object’s value in relation to those criteria” (2004, p. 5). While the efforts to evaluate this product were fairly extensive, the evaluation was primarily formative in nature. A formative evaluation is designed to provide information to improve the product (in this case as the product is being designed and developed), as opposed to a summative evaluation, which is intended to aid in the judgment of the product’s overall worth (Fitzpatrick et al.).

Fitzpatrick et al. (2004) suggest that an evaluation is ineffective if it doesn’t take into account the concerns and questions of each stakeholder. The primary stakeholders were determined to be Dr. Larrie Gale (the sponsor), the designer, and the students of the

TMA 271 course. Each stakeholder was interviewed early in the design process, including past TMA 271 students, to understand the desired objectives of the instruction and the target audience, but also to formulate questions that the various parties would want answered concerning the LIDS lesson. These were informal interviews, and the responses and comments made by the participants were analyzed to determine a list of questions and criteria. These questions were then reviewed and agreed upon by the various stakeholders.

The evaluation questions are as follows: (a) Does the lesson function properly on a technical level? (b) Is the LIDS lesson easily navigable? (c) Does the LIDS lesson function as stand-alone instruction? (d) Does the lesson aid students in their understanding of LIDS principles and concepts? (e) Does the lesson aid students in their ability to apply LIDS principles to practical situations? (f) Do students feel that the lesson was a worthwhile experience? (g) Do the students think that the various elements (animation, interactivity, questions) were useful in helping them learn? A complete table of questions, criteria and standards are presented in Appendix D.

The model set forth by Dick, Carey, and Carey (2000) suggests four main phases for conducting an evaluation of instructional material: specialist reviews, clinical or one-to-one evaluation, small-group evaluation, and a field trial. Due to the number of participants available for this evaluation, the small-group evaluation was merged with the field trial for a single session.

Specialist Reviews

While much of the formative evaluation process focuses on gathering data from the learners, of equal value is the assessment of specialists that review the product (Dick,

Carey, & Carey, 2000). Here the focus shifts from the effects of the product to the product itself. The designer has a tendency to become so involved in the project and the content, that it becomes useful to expose the product to a fresh set of opinions. This process is particularly useful in the early stages of design and development (Paas & Firssova, 2004). This product was reviewed by two different groups of specialists: subject matter experts (SMEs), and specialists in instructional design.

Subject Matter Expert Reviews

The services of two SMEs were solicited for reviewing the content of the LIDS lesson: the sponsor, Dr. Larrie Gale, and a local producer who creates computer-based instruction and is well-versed in the technology behind it. The lesson designer met with Dr. Gale periodically during the design and development phases of the LIDS lesson. The lesson in its various stages was presented, a number of informal questions were asked, and feedback was provided on the part of Dr. Gale.

The review efforts of Dr. Gale were invaluable in a number of areas. The initial lesson outline came from the notes he had been using as part of his course curriculum, It was revised based on discussion about the appropriate order of topics and what content should be added and subtracted. His experience in teaching the subject matter contributed a great deal to the decisions made in creating the script, such the inclusion of several examples that had been used successfully in the classroom. Dr. Gale's familiarity with the audience was also helpful, as several of the more complex concepts were written with clarity in the eyes of the designer, but were eventually simplified or drawn out for better audience comprehension. During the latter stages of development, Dr. Gale made occasional comments on the graphics or animation that helped to increase the accuracy

and clarity of the content, such as providing a gradient for the CIE chromaticity diagram as opposed to well-defined areas.

The services of the second SME were utilized primarily during the writing of the script, which contained both the verbal content and descriptions of how that content would be presented. The designer met with him twice during this period to receive feedback based on the reviewer's assessment of the script. Having an in-depth knowledge of the subject matter, the SME was particularly helpful in refining the language of the script for increased accuracy, and in aligning the terminology more closely with that used in the production industry.

Instructional Design Specialist Reviews

Due to their experience in designing or critiquing various forms of instruction on a regular basis, instructional design specialists can be an especially effective tool in obtaining an informed, outside opinion of the product's strengths and weaknesses (Preece, 1993). In addition, little prompting is necessary to draw out those suggestions, compared to working with sample audience participants in the clinical evaluation.

At three different stages in the design and development of the LIDS lesson, materials were distributed for review by three specialists in instructional design. The specialists received a script during the design stage, and a phase one and a phase three prototype during the development stage. The specialists were generally left to review the materials on their own time, and submitted comments to the designer. There were usually a few specific questions provided from the designer, but for the most part the review process was informal and left up to the specialists. These specialists reviewed the

instructional strategies of the lesson with the end user in mind, and commented on the weaknesses and strengths of the lesson's potential as an effective instructional tool.

The instructional design specialists made a number of comments that were helpful in refining the effectiveness of the lesson. They encouraged the inclusion of more interactive elements that could simulate how the principles discussed would occur in “the real world.” This resulted in the development of several activities, including the rods and cones slider example in Module Three, which could help the students visualize cause and effect relationships involving the LIDS principles. The specialists also expressed a concern during the first two reviews that the lesson contained content that was presented too quickly. This was a concern of the designer in the initial design stages, balancing a lesson that would cover a breadth of information without compromising the depth that would help the student grasp the principles. While the script was written with this challenge in mind, the comments of the specialists were valuable in providing a different viewpoint of the material, and pinpointing areas that, at the very least, should be focused on during the clinical evaluations.

Clinical Evaluation

The purpose of the clinical, or one-to-one, evaluation is “to identify and remove the most obvious errors in the instruction, and to obtain initial reactions to the content from learners” (Dick, Carey, & Carey, 2000, p. 286). Many sources that discuss clinical evaluation and product usability testing suggest a similar pattern (Dumas & Redish, 1999; Preece, 1993; Dick, Carey, & Carey, 2000). A participant, ideally a representative of the target audience, is situated in front of the product and required to experience it as though it were part of a course curriculum. The evaluator is most often present, and

requests that the participant verbalize their thoughts as they progress through the lesson. The evaluator takes notes on the participant's comments, as well as any observed difficulty or problems that the participant encounters. This process was followed with three participants at three separate stages of product development, using a paper-based prototype, a low-fidelity prototype, and a high-fidelity prototype. In addition, the participants were also asked to review or complete the evaluation instruments that had been developed for the small group evaluation. This allowed the pre/post-test and the questionnaire to be refined at the same time as the LIDS lesson.

Paper-Based Phase

After the LIDS lesson script was completed and had been reviewed by the subject matter experts, the designers debated whether or not to conduct a clinical evaluation at this stage. The script relied primarily on audio narration and visual elements, and the amount of accurate feedback that could be given was doubted. In the end, however, quickly sketched storyboards were presented as the designer read the narration to the participant, providing a glimpse of what the final product would entail. It proved difficult for the participants to voice their thoughts during the presentation (presumably not wanting to interrupt the designer), so the designer paused on occasion to solicit feedback.

This paper-based phase focused on the following three questions: (a) *Is the LIDS lesson easily navigable?* (b) *Does the LIDS lesson function as stand-alone instruction?* (c) *Do students feel that the lesson was a worthwhile experience?* The most consistent comments that led to revision concerned the first question. While it was difficult for the participants to imagine how the interface of the end product would look and feel, and at this stage they weren't given the opportunity to click on buttons to see the result, each

participant did express concern that they weren't sure what would happen if they pressed the buttons. While they could guess, the buttons themselves weren't intuitive enough to know their functions by sight alone. In addition, when asked about the module buttons at the top of the interface, each participant assumed that they showed the location of the user, but none of them guessed that they also functioned as buttons to navigate through the modules. The subsequent revisions included clearer button icons, and an opening segment that serves as instructions for navigation and other items that the user can expect.

Overall, the feedback from the paper-based evaluation phase was encouraging, and more valuable than anticipated. The students enjoyed the casual tone of the narration, and expressed interest in using an instructional module that employed animation and interactivity. During this phase, the review of the evaluation instruments was primarily a semantic review, since the lesson had not been completed to the extent that the participants could complete a test on the material.

Low-Fidelity Phase

The low-fidelity evaluation phase utilized a prototype of the LIDS lesson that contained the majority of the graphics and much of the animation, in sync with the narration, as well as most of the navigational options. Placeholders were provided for the end-of-module questions and the interactive elements, which had not yet been developed. Again, three participants representing the target audience were invited to participate in the lesson, as well as in the evaluation instruments. The evaluation questions addressed in this phase were the same as those addressed in the paper-based phase, with the addition of (d) *Does the lesson function properly on a technical level?* One of the greatest benefits

of the low- and high-fidelity clinical evaluations was the uncovering of bugs and other technical issues, particularly in the navigation.

An issue that became immediately apparent with all three participants was the annoyance with the frequency of forced pauses throughout the lesson. The linear presentation paused periodically (perhaps every minute in a seven minute module), inviting interaction from the user, and forcing them to take time to consider the material covered. The participants were bothered by the frequent pauses, wanting the presentation to flow continuously, allowing them to pause only when needed. This argument concerned the designer, considering that this feature was based on empirical studies (Mayer & Chandler, 2001). In the end, the decision was made to reduce the number of forced pauses without eliminating them entirely, knowing that the forthcoming interactive elements and the module review questions would also help to create a more deliberate pacing. After these revisions, this problem did not surface in future evaluations.

Occasionally comments were made that suggested good features, but ones that were not practical or possible given the project resources. Several participants, for example, suggested providing fast-forward and rewinding capabilities to the navigation, in addition to the Next and Previous buttons. While this would certainly make the lesson more accessible, it was not an option within the programming capabilities of the designer.

Comments on cosmetic items were also helpful; the participants liked the look and feel of the overall interface, but thought that the rollovers on certain buttons were not distinct enough. Few negative comments were made on the content itself, though one participant expressed confusion in Module Five concerning how the human eye can see a

greater range of colors than computer monitors can represent, yet a computer monitor can present more colors than the eye can see. The designer decided not to make any revisions based on this reaction, perhaps due to the struggle it had been to develop that section in the first place.

High-Fidelity Phase

The high-fidelity evaluation phase used a LIDS lesson version that was quite close to the finished version. All of the graphics and animations were in place, as well as the interactive elements, the module review questions, and the extra content buttons. Lacking were a few cosmetic elements, including a professional-quality voice recording and introductory music.

This phase looked at all seven evaluation questions. The evaluation instruments were given to the participants, but again only in order to refine the instruments themselves. The primary source of feedback was still the comments of the participants, during and after they experienced the LIDS lesson.

The question, *Does the lesson aid students in their understanding of LIDS principles and concepts?* was addressed when two of the participants raised the Module Five issue that had been dismissed in the previous phase, concerning the color abilities of the human eye and the computer monitor. After reworking the section several different ways, the designer finally developed a presentation of the concept that, per the recommendations of the instructional design specialists, added more depth to the concept. The new presentation also incorporated a model that had been used previously in the LIDS lesson, which helped to tie several principles together. This revision was utilized during the small group evaluation, and received only positive comments.

During this phase, the designer noticed that the participants didn't use some of the features in the lesson, such as pressing the spacebar to move from one section to the next, or clicking on the extra content buttons. When asked why they didn't use that feature, the participant usually responded with a variation of "Oh, it can do that? That's helpful..." Though these features had been discussed in the opening instructions, it was determined that the participants weren't encouraged to pay close attention to them. The opening instructions were therefore revised, changing from a static paragraph of text, to an audio introduction with graphical highlights of the navigational options being discussed.

As a whole, the process of creating progressively complex prototypes for evaluation proved very valuable. Each of the evaluation questions was addressed to some degree, shedding light on everything from technical errors to content issues. In addition, it gave the designer confidence that the lesson was enjoyable and beneficial for the user.

Small Group Evaluation/Field Trial

According to Dick, Carey, & Carey (2000), the small group evaluation is designed to determine the effectiveness of the changes made during the clinical evaluation, and to determine if the product can be used independently of the instructor. They suggest a group of eight to twenty participants that match the ideal target audience as closely as possible, engaging in the instruction as delivered by the evaluator. The field trial is designed to determine if the instruction can be used effectively in the environment for which it was intended. In an educational setting, it differs from the small group evaluation in that the participants *are* your target audience, and the instruction is implemented by the instructor as part of the pre-determined curriculum (Dick, Carey, & Carey, 2000).

Due to the circumstances and resources available to the designer, characteristics from both methods were used in the same evaluation test. The lesson was implemented with Dr. Gale's TMA 271 course during the fall semester of 2004, at the point in their course curriculum when the LIDS material is normally discussed. The students participated in the instruction as designed for class implementation, although the designer conducted the class, and evaluation instruments were introduced and used.

Description of Participants

All of the seventeen participants in the evaluation were university students enrolled for credit in Dr. Gale's TMA 271 course. Thirteen of the students had been accepted into the Media Arts program, while the remaining students were either applying to the program or pursuing different majors. All of the students participated willingly in the evaluation, though Dr. Gale required the students to return the questionnaire for class credit.

Evaluation Instruments

As previously mentioned, evaluation instruments were developed concurrently with the instruction, and tested and refined during the clinical evaluation process. These instruments consisted of a criterion-referenced pretest and posttest, and a post-lesson questionnaire.

The pre/posttest (see Appendix E) was designed to measure the ability of the student to meet the specific learning outcomes of the lesson, and to answer the following stakeholder questions: (a) Does the lesson aid students in their understanding of LIDS principles and concepts? (b) Does the lesson aid students in their ability to apply LIDS principles to practical situations? The tests contained eleven items, six of which were

multiple choice, and the remaining five were short essays. Seven of the questions addressed the students' understanding of the LIDS principles, and four addressed their ability to apply the principles to practical situations. The pretest and posttest were identical in the content of the items, however the item order and wording was altered from one test to the other.

The questionnaire (see Appendix F), designed for completion after participation in the LIDS lesson, contained ten open-ended questions addressing the student's experience with the lesson. Part of the purpose of the questionnaire was to address the following stakeholder questions: (a) Does the lesson function properly on a technical level? (b) Is the LIDS lesson easily navigable? (c) Do students feel that the lesson was a worthwhile experience? (d) Do the students think that the various elements (animation, interactivity, questions) were useful in helping them learn?

These evaluation questions corresponded almost directly with an item on the questionnaire, such as "Did you encounter any technical difficulties or bugs during your experience?" or "Did you find the interactive activities helpful? Explain why or why not." Other questions were intended to address specific issues the designer hoped to gather information on. The item "Did you feel that any particular topic went by too quickly to gain an understanding of it? Which topic(s)?" was included to determine if the pacing issue discovered earlier in the design process had been eliminated. Printed on the questionnaire was also a list of the modules in the lesson with a brief description, designed to help the students recall their experience and specific elements in a module that they wished to comment on.

Procedures

Working with Dr. Gale, the designer scheduled the evaluation to take place at the point in the curriculum when the class would normally discuss the concepts of light in digital space. On the day when the lecture and discussion normally would have taken place in class, the designer visited the class and gave a brief introduction to what was occurring. The pretest was distributed and completed by the students, after which a CD-based version of the project and a questionnaire was distributed to each student. They were instructed to spend some time on their own with the lesson on the CD, whether at home or wherever they had access to a computer, treating it as part of the class curriculum. They were requested to respond to the items on the questionnaire after completing the lesson, and were informed that the questionnaire would be returned for class credit and a test would be administered on the content during the next class period, two days later.

The students returned to class two days later and turned in their completed questionnaires. The posttest was then administered to the students. After the posttest, a short class discussion was led by the designer concerning the students' experience, in which they primarily tended to repeat items they had already described on their questionnaires. The questionnaire responses were reviewed and tabulated, and then compared with the evaluation questions they were intended to address.

Qualitative Results and Discussion

The questionnaire completed by the students after experiencing the lesson, and the subsequent short class discussion, were the primary sources of qualitative data. The following paragraphs describe how these sources addressed several of the stakeholder

questions, as listed previously. For a complete tabulation of the questionnaire items and the student responses, see Appendix G.

Does the lesson function properly on a technical level? Stakeholders required that the lesson be free from technical error or difficulty from startup through the end of the lesson. Responses indicate that most students did not encounter any difficulty with technical aspects. One student, using a Mac platform, reported not being able to view elements of the review questions. Further investigation revealed that the system did not have the proper version of the Flash Player. This was easily remedied by placing a version checker in the program's startup file.

Is the LIDS lesson easily navigable? The lesson needed to have a navigational structure that allowed the user access to what they required, while making those options clear to the user. The button configuration and the instructions on how to use them should be simple and understandable. Most participants reported that they did not experience any problems with the navigation, and several expressed that they enjoyed the amount of control they had over their experience. Those that did respond with navigational problems mostly returned to issues that had been uncovered during the clinical testing, including the desire to fast-forward through the modules, and an annoyance at having to constantly click the button. As mentioned earlier, these issues had already been addressed to the extent deemed appropriate by the designer. One participant mentioned a difficulty starting out with so many icon choices, but this was limited to a single response.

Do students feel that the lesson was a worthwhile experience? An important aspect of the lesson for all of the stakeholders is the students' attitude toward their experience. The motivation of the students to learn is low if they do not see the relevance

of the material, if their attention is not kept, or if they are not otherwise satisfied by their experience (Driscoll, 2000). The overall response to the questionnaire items was positive – there were no comments indicating that students did not find the lesson enjoyable or useful. The various computer-based elements were well-received, with comments that they helped to maintain attention, focus the students' thoughts, and make the experience more enjoyable. With the exception of the temporary voice-over, the students also considered the lesson to have a “professional look and feel,” which gives the learner more confidence in the experience.

Do the students think that the various elements (animation, interactivity, questions) were useful in helping them learn? Early in the design process, the designer and sponsor decided to create a computer-based lesson in order to take advantage of the various interactive media elements that the platform offered. While the design was user-centered, the interactive media elements played a large part in the experience of the LIDS lesson. In considering the evaluation questions, the stakeholders logically wanted a way to consider the effectiveness of these elements. It was difficult to break out these elements from the overall student test performance, and therefore the focus was placed here on the students' perceptions of how useful the individual elements are.

The animation and interactive elements were very well received. The students' commented that the animations were helpful in visualizing the concepts, and the interactivity “showed instead of told” how the concepts work, while also providing an opportunity for practice. Along those same lines, when asked if they would rather use a computer-based module or a traditional textbook, the majority of the students claimed

that they would prefer using a computer-based module, due to the unique elements it provides over textbooks.

The module questions were also well-received, especially as opportunities for review, but gathered more negative comments than the other elements. The negative comments do not criticize the use or the nature of the questions, but primarily the wording, which some considered confusing. The content of the questions were also criticized, as a few struggled to find relevance to the material covered. This is presumably due to the questions that attempt to help the student anticipate how the material will relate to content yet to be presented, or to situations in the real world.

Quantitative Results and Discussion

The quantitative data gathered in the small group test came primarily from the pre-test/post-test administered to the students during class. The quantitative data helps answer the two remaining evaluation questions as prepared by the stakeholders: (a) Does the lesson aid students in their understanding of LIDS principles and concepts? and (b) Does the lesson aid students in their ability to apply LIDS principles to practical situations?

The mean for the pre-test scores was 7.43 out of 20 possible points, with a standard deviation of 3.16. The mean for the post-test was 14.14 with a standard deviation of 3.20. This produced an average gain of 6.72 points, or 90.56%. A paired samples t-test showed the difference between means to be statistically significant, $t(13) = -7.475, p < .05$. While the testing circumstances were not as controlled as they could have been, practical significance is suggested in the fact that they mirrored the methods that will be used when the lesson is implemented (i.e., taking the lesson home).

In summary, the qualitative data from the questionnaire answered a number of the evaluation questions posed by the stakeholders. The response from the students was generally favorable; they pointed out a few items that required alterations, but their criticisms were mostly minor or limited to one or two students. The quantitative data suggests that the lesson facilitates the learning and application of the LIDS principles.

Critique

The LIDS Lesson

Perhaps one of the greatest weaknesses of the LIDS lesson was found in the computer-based structure, which is currently only divided on a high level into individual modules. It seems that the user would also benefit from a further classification of subsections within each module; for example, whenever the user is required to click the *forward* button, it would define a new “page” or subsection. The user would be provided with a visual representation of which page he/she is on, similar to the representation of which module is open, and allowed instant access to the various pages. This access would give the user a greater control over the experience, and would also provide a better sense of their exact location within the lesson. In addition, it would allow an incorrect answer in the review questions to direct the user back to a specific point in the lesson. This feature is currently unavailable due to the lack of specific navigational access, but was suggested by one of the small group users.

Another weakness of the lesson was considered early in the development process and dismissed by the designer, but resurfaced again in the small group test. When asked on the questionnaire which aspect of the lesson they liked the least, a number of participants responded with “Module Four: Bits and Pixels” because it was a brief

module that covered material they already knew. While the designer considers the material in that module necessary as a review and foundation for subsequent concepts found in Module Five, perhaps the content of Modules Four and Five is poorly divided. Were the content simply combined into one module, it would prevent the dissatisfaction expressed with the brief and rudimentary Module Four. It would also link the content of the two modules together, giving a greater focus to the new material for those that already understand the review content.

Following the events set forth by Gagné (1979), another weakness is a neglect to properly inform the learner of the objective. While a general statement of what is expected of the user is given in the introduction, perhaps a series of more specific objectives stated in each module would have provided a better cognitive organization of the material for the user.

The LIDS lesson certainly has strengths, as well, with the media elements at the top of the list. The use of animation, audio, graphics and interactivity has been carefully researched and implemented in the lesson following recommendations based on numerous empirical studies (Clark & Mayer, 2003; Mayer, 2001; Rieber, 1991). In addition to serving as effective learning tools, the qualitative data from the small group test suggest that these elements were also very well received by the users, increasing their interest in the lesson and their motivation to learn and gain from it.

The lesson is also effective in focusing not only on the content of the LIDS domain, but also on its practical application. The review questions and the interactive elements in particular aid the user in discovering how these principles can apply to actual situations they will encounter in dealing with multimedia production.

The Design, Development and Evaluation Process

The primary weakness of this development process is one shared by many projects initiated by graduate students: the designer is the sole source of labor. While others generously contributed time to evaluate the product and related materials, the script writing, graphic design, interface design, animation construction, programming, copy editing, audio recording and hot chocolate production are all the responsibility of the instructional designer. While the designer is able to accomplish all of these tasks, he is certainly not a specialist in each area. The quality of the end product, and the efficiency of the schedule, could certainly have been enhanced by recruiting specialists in these creative areas.

A specific weakness occurred during the small group evaluation/field test. Due to the resources available, the small group test and the field test were combined into one session that required the students to take the lesson outside of class to complete it. While this is how the eventual implementation of the product will function, and is consistent with a field test, it made it difficult to know how well the students actually completed the lesson, or if they completed the lesson at all. Had the time and resources been available to provide each student a computer in class and have them complete the lesson under observation, this concern could have been eliminated.

One of the strengths of the design and evaluation processes was the relationship and interaction with the various stakeholders. By working with the sponsor, the target audience, and other stakeholders from the initial stages through the evaluation, a greater understanding of their needs and expectations was gained. It also provided more assistance when it came to the logistics of conducting the evaluation.

Schedule

A schedule for the design and development of the LIDS lesson was drafted during the initial stages of the project. Despite the fact that the lesson was intended to be delivered in time for classroom use during the appropriate point in the curriculum, the project began early enough that the schedule was fairly flexible (see Table 1). The major setbacks in the schedule were initiated by the sponsor, by delaying the date for the classroom field test, and requesting a specific talent for the voiceover who was unavailable for some time. In the end, the scheduled milestone most important to the stakeholders, the high fidelity prototype for evaluation, was delivered in time for the field test.

Table 1
Estimated and Actual Milestone Deliveries for the LIDS Lesson

Milestone	Projected Delivery	Actual Delivery
Content outline	August 11	August 10
Script – final draft	August 17	August 17
Interface design and prototype	August 23	August 20
Complete evaluation tools	August 25	August 25
Complete graphics for animation	August 27	August 28
Complete audio narration	August 27	August 27
Complete animations	September 8	September 11
Prototypes of interactive elements	September 13	September 15
Complete interactive elements	September 24	September 29
High fidelity product for evaluation	September 29	October 4
Final product complete	October 15	October 20

Budget

A budget was also developed during the initial stages of the project, comprised of personnel expenses and material expenses. While the material expenses were actually incurred, the personnel involved were not monetarily compensated for their efforts. The

personnel rates shown in Table 2 are therefore based on information provided by the Office of Research and Creative Activities at BYU, with the designer/developer billing as a graduate student.

The most significant expense was the services of the designer/developer, who provided the majority of the labor for the project. The actual labor exceeded the estimate by seven percent, which is a reasonable excess considering the number of hours required for the development of the product. Other personnel accounted for include the instructional design specialists, the subject matter experts, and the voice recording talent. At the time of this report, the voice talent has not yet been utilized, and is a responsibility left to the sponsor.

Material expenses were fairly minimal, the bulk of which include the Macromedia software necessary to complete the product development. The production location, including utilities overhead, was provided by the designer. Materials required for the small group test are also factored into the budget.

Table 2
Projected and Actual Expenses for the LIDS Lesson

Expense	Estimated Units	Actual Units	Unit Rate	Estimated Cost	Actual Cost
Personnel					
Designer/Developer	285 hours	305 hours	\$15/hr	\$4,275	\$4,575
ID Specialists	12 hours	12 hours	\$25/hr	\$300	\$300
Voice talent	3 hours	n/a	\$15/hr	\$45	n/a
Subject Matter Experts	6 hours	4 hours	\$25/hr	\$150	\$100
Materials					
Macromedia Flash (academic version)	1	1	\$150	\$150	\$150
Paper Printouts	150	120	\$.04	\$6	\$4.80
Distributed CDs	30	25	\$.30	\$9	\$7.50
Personnel				\$4,770	\$4,975

Materials	\$165	\$162.30
Grand total	\$4,920	\$5,137.30

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Appendix A

LIDS Lesson General Instructional Objectives & Specific Learning Outcomes

1. Understands the basic relationship between color and light.
 - 1.1 Identifies the primary colors associated with each type of light
 - 1.2 Explains the difference between additive and subtractive light
 - 1.3 Predicts how color/light will react in given situations
2. Understands how the anatomy of the eye functions, in relation to light and color.
 - 2.1 Identifies the roles of cones and rods
 - 2.2 Explains the difference between chrominance and luminance in relation to the human eye
 - 2.3 Explains how rods and cones react in different lighting situations
3. Understands the relevance of the Chromaticity Diagram.
 - 3.1 Describes the elements of the Chromaticity Diagram
 - 3.2 Explains the relationship of the Chromaticity Diagram to what we see
4. Understands how computers represent information.
 - 4.1 Determines the number of possible combinations given the number of bits
5. Understands the function of a pixel.
 - 5.1 Defines a pixel and its construction
 - 5.2 Predicts the resulting color from a set of pixel phosphors
6. Understands the purpose of bit depth
 - 6.1 Explains the use of bit depth in graphics
 - 6.2 Explains the trade-off between file size and fidelity
 - 6.3 Explains the purpose of the three RGB channels in 24-bit graphics

- 6.4 Applies the concept of bit depth to a production situation
- 7. Understands how computers utilize color models
 - 7.1 Explains the purpose of color models
 - 7.2 Contrasts the use of RGB and CMYK color models
 - 7.3 Applies the concept of color models to a production situation
- 8. Understands CODECs can function with computers and the human eye
 - 8.1 Explains how a basic CODEC works
 - 8.2 Describes how lossy CODECs differ from lossless
 - 8.3 Applies the concept of CODECs to a production situation

Appendix B

Extra Content Options Text

Digital Space

There are a lot of different places you can use the word "digital," and not all of them carry the same meaning. Compared to an analog watch (with moving hands), a watch that uses LCDs is considered digital. But an ordinary television isn't considered digital compared to an HDTV, due to the type of signal they are capable of receiving. The most basic version of the definition "digital" refers to something that uses discrete, or individually distinct, values, as opposed to a continuous array of values (such as analog). The word comes from the Latin source word "digit," meaning finger (as in, to count on your fingers).

For the most part, during our discussion here we will be referring to the digital space represented by a computer. You'll certainly notice, however, that some of the principles we discuss will also apply to other "spaces" that could be considered digital, such as televisions

Light wave

We say here that light is a wave, but that's only half of the story. This theory was proposed in the late 1700's because scientists noticed that light would often exhibit behavior that was most easily explained by it being a wave (such as diffraction). But during the same period, Isaac Newton built on the work of others to propose that light is comprised of particles that emit in all directions from the light source. One of his arguments for particles over waves was the idea that waves bend around objects, but light only travels in a straight line.

Albert Einstein joined the discussion several centuries later, and won the Nobel Prize for his work with the wave-particle duality theory. This suggests that light shares both a particle nature and a wave nature. This continues to be a focus for science, however, and we still can't say we know exactly what light is "made of". We discuss light here as a wave simply because it is traditionally measured and categorized by its wavelengths and frequencies.

Electromagnetic Spectrum

Light is a form of electromagnetic radiation (a type of energy) that can be found throughout our galaxy and others. But not all electromagnetic radiation is light - only the wavelengths that the eye can see. The electromagnetic spectrum represents all possible wavelengths of electromagnetic radiation - from electric power at the long-wavelength end, to gamma radiation at the short-wavelength end, including waves that are thousands of miles long to those that are a fraction of an atom. Within the spectrum lay microwaves, radio waves (including AM, shortwave, UHF, VHF), infrared radiation, x-rays and, as shown here, the wavelengths that we can see: light.

Primary Colors

A primary color is a color that cannot be created by using other colors in the gamut (or the system of color being used, such as additive light). In the case of additive light, red, green and blue are primary colors because they can combine to create any color, but no colors can combine to create one of them.

You might be thinking to yourself, "But my third grade teacher, Mrs. Ernwinkle, told me that the primary colors are red, yellow and blue..." While Mrs. Ernwinkle probably had the greatest of intentions, she was largely incorrect. Tradition (and

elementary school) teaches that red, yellow and blue are primary because this is what's seen when using crayons or paints. However, crayons and paints are not true color representations - the yellow may look like true yellow (and even say so on the paper label), but it isn't exact. So while working on the coloring book pages you might get all of the colors you need by combining red, yellow and blue, that won't hold true anywhere else. As well discuss shortly, in any type of printing, where color is more measured and exact, the primary colors are cyan, magenta and yellow. And additive light is an entirely different way of seeing things, and uses red, green and blue.

Absorb Light

Absorption is the process in which an object takes in the energy of a photon that strikes it. We don't see the wavelengths of light that are absorbed because their energy has been transferred to the object, which stores it.

Reflect Light

When two dissimilar media (such as air and the banana) interface, there can be an abrupt change in the direction of a wave. Instead of being absorbed (or transferring its energy to the object), the wave simply changes direction. Reflection of light can be "specular," where it retains an image, such as in a mirror. It can also be "diffuse," where it retains the energy, but not the image, such as light bouncing off the walls.

Pupil

In the eye, the pupil is the hole in the middle of the iris. It appears black because most of the light entering it is absorbed by the tissues inside the eye - in fact only a small part of the light that enters actually reaches the retina. In humans and many animals, the

size of the pupil is controlled by involuntary contraction and dilation of the iris, in order to regulate the intensity of light entering the eye. This is known as the pupillary reflex.

Chrominance

While chrominance is a term that is used often when discussing the signal that a television receives or the image it produces, it also aptly describes what the cones in our eyes see. As far as our eyes are concerned, what we see is really only comprised of chrominance and luminance. Chrominance is the color information that they receive, defining a single color in relation to another color.

Luminance

Luminance is also term often used when discussing video signals, but one that has application to what the eye sees. In addition to chrominance, the eye detects luminance, which is the degree of brightness an object has. Since rods control both luminance and the amount of detail we see, we tend to see more detail in the luminance information we take in than the chrominance.

Pigments

Cone pigments refer to the chemicals in the cones that respond to light. These are very similar to the chemicals in the rods, except that they respond to the lightwave frequencies (and therefore color) opposed to the intensity of the light. Each cone cell has one of these pigments and responds to that color.

CIE

The International Commission on Illumination (usually known as the CIE for its French-language name Commission Internationale de l'Eclairage) is the international authority on light, illumination, color, and color spaces. They have helped to set

standards for color and light, which affect everything from plastic molding to UPS' patented brown color.

Hue

A hue refers to the gradation of color within the visible spectrum of light. It may also refer to a particular color within this spectrum, as defined by its dominant wavelength. You can choose a color on the spectrum and call it "purple" because it falls into that category as defined by its wavelengths. But if you move slightly to the right on the spectrum, the color looks a little different, but is still a "hue" of purple.

Saturation

Saturation refers to the intensity of a specific hue, and is based on a color's purity, meaning how spread out it is across the spectrum of different wavelengths. The purest color (and therefore the most saturated) is achieved by using one single wavelength, such as seen in a laser.

“Pixel Dots”

We use the generic term "dots" here because the material and the shape of the dots varies depending on the instrument. In most CRT and LCD computer monitors, for example, the dots are phosphors (material that glows when hit with energy) that are arranged in group similar to what you see here. Some televisions also use phosphors, but arrange them as rectangles in stripes. In either version, the phosphors glow when struck with an electron beam that corresponds to their color.

Alpha Channel

An alpha channel is a matte embedded in an image that is used in graphic design and other fields. It allows the image to carry a predefined selection for transparent

backgrounds or other purposes. In the simplest 2D image with an alpha channel, the element which stores the color for each pixel also stores a 1 or a 0 in the alpha channel - 1 if the pixel is fully opaque, 0 if there is no coverage. In 32-bit color, there is a full 8-bits devoted to the alpha channel in each pixel, which allows the channel to have gradients (i.e., it can gradually fade).

Data Rate

The data rate is the speed at which an element, such as a video clip or still image, communicates with the computer. Generally speaking, the higher the quality of the media element, the higher the data rate, since there is more information to transfer to the computer. In media elements that have a temporal dimension, such as video or audio clips, you can determine the data rate as part of the compression settings. With still images, data rate mostly comes into play when you're transferring them over the internet, a network, or a CD.

Algorithm

An algorithm is a finite set of well-defined instructions for accomplishing some task (such as compressing an image file, though algorithms can be found in all areas of mathematics and logic). The concept of an algorithm is often illustrated by the example of a recipe, although many algorithms are much more complex. Algorithms often have steps that repeat (iterate) or require decisions (such as logic or comparison) until the task is completed.

Different algorithms may complete the same task with a different set of instructions in more or less time, space, or effort than others. For example, given two different recipes for making potato salad, one may have peel the potato before boil the

potato while the other presents the steps in the reverse order, yet they both call for these steps to be repeated for all potatoes and end when the potato salad is ready to be eaten. In some countries, such as the USA, some algorithms can effectively be patented if a physical embodiment is possible (for example, a multiplication algorithm may be embodied in the arithmetic unit of a compression software application).

Appendix C

Multimedia Script for the LIDS Lesson

#	<i>Narrator Script</i>	<i>Screen Visuals</i>
1.0	<p>Welcome to the lesson, <i>Light in Digital Space</i>, where we're going to discuss some important issues in multimedia production.</p> <p>First, take a look at the interface you're going to use during this lesson. These titles at the top represent the various topics we're going to discuss. The ball shows you where you are. If you want move to a different topic, click on the title.</p> <p>Keep your eye on these boxes. When a term or concept is mentioned that you're unsure of, or would like to learn more about, chances are it will appear here. You can click on it to learn more.</p> <p>Here are your navigational buttons. Forward will move you to the next section, and Previous to the section you just finished. Pause, well, pauses. On occasion we'll stop for you to think about what we're discussing or to take notes. When this happens, the Forward button will turn green, and you can click on it or press Spacebar when you're ready to continue.</p>	<p>As a specific part of the screen is mentioned, an arrow appears, directing the attention of the viewer to that area.</p>
1.1	<p>(Music up) When it comes to visual communication everything depends on one single element. Light. Lovely painting isn't it? One of my favorites... But as you look at a painting that hangs on the wall, have you ever wondered why it is that you can see it? What happens between it and your eyes that gives the things in this painting shape and color and depth in your mind?</p>	<p>Darkness. Light comes on, spotlight on a painting.</p>
1.2	<p>And what if you were viewing a digital representation of this painting, on a computer screen, for example? If you ask yourself the same question, <i>why do you see it?</i> you'll get a different answer. (Music down)</p>	<p>Computer superimposed over the top</p>

1.3	<p>Right now we're going to discuss how light is represented in digital space. That is, how computers and video use light and color to create the visual representations we see. First, we'll talk about the nature of light, and its relationship to color. Then, we'll see how our eyes discern light and color. Third we'll look at how computers represent visual information. And then we'll tie it all together by talking about how computers use the way we see light in order to reduce the amount of information they have to deal with.</p>	<p>Flow chart of the four main segments.</p>
2.1	<p>First let's talk about some basic ideas of light and color. You've probably heard in your physics class that light, at least in part, is a wave. Like all waves it has a variety of frequencies. Frequency refers to the number of waves that pass a certain point during a specified amount of time. Our eyes can only see a limited number of light frequencies, and we call those different frequencies "color." Visible light is only a small part of all the frequencies of waves that exist, as seen here on the electromagnetic spectrum.</p>	<p>Simulated light wave Measurement of frequencies, turns into the spectrum, with the visible colors supered out.</p>
2.2	<p>We can see the nature of visible light when white light passes through a prism, which separates the light into a rainbow spectrum. If we divide the spectrum up into thirds, the predominant colors are red, green, and blue. These three colors are very important, so keep them in mind.</p>	<p>Colors move over as the light moves through the prism. The spectrum is reduced to those three colors.</p>
2.3	<p>There are actually two different ways to reproduce color. The first is called additive color. This occurs when light is emitted from an object, like a light bulb. This light uses the additive primary colors of red, green and blue in order to create other colors. When red light and green light are added together, they create yellow light. Green and blue light create cyan; and red and green create yellow. When all three colors are combined, white light is produced. As you look at this diagram, you can think of it as three flashlights covered with colored pieces of cellophane, shining</p>	<p>"Additive color" Light bulb turns on. Circles of color as they are mentioned, in a Venn diagram</p>

at the wall. Turn the lights on and off, and you can see how they react to each other...

2.4	(Omitted)	
2.5	So additive color involves the use of colored lights, mixing red, green and blue together to create colors. Televisions, computer monitors, and neon signs are all examples of additive color.	Photos of these objects.
2.6	But what about magazines, or paintings, or ordinary objects like a banana? We see color in these objects because of subtractive color. Let's take our banana and put it outside in the sun, which is white light – a combination of all visible lightwave frequencies. The banana is hit by rays of light, and it absorbs the blue rays, among others, but reflects most of the red and green rays (which, as we discussed, make yellow). These rays reach our eyes, and we perceive the banana as yellow. This is the way that subtractive color works – an object absorbs, or subtracts, some wavelengths and reflects the others. Those reflected wavelengths reach our eyes, which we perceive as the color of the object.	Photos of these objects. Banana remains in B&W, backdrop of the outdoors falls in behind it. Light ray hits the banana, red and green bounce off, hit a person's eyes.
2.7	Now here's a question for you. Say we take the banana and put it in a room and turn out all of the lights. Then we shine a blue light on the banana. What color will the banana be? Think about it...	Background turns black, blue spotlight on banana with ? mark. (QUESTION) Color options.
2.8	That's right. <i>(Incorrect feedback: Well, actually, it would be black).</i> If the blue light is the only light in the room, we know that the banana will absorb nearly all of the blue light, leaving nothing left to reflect. The banana will appear black, or at least a very dark gray. (Review Questions)	Banana appears black in the spotlight.
3.1	Now, you're sitting there thinking to yourself, "That's fascinating. But how does my brain know that it's seeing color...?" Well, that question leads us to our next topic – the human eye.	Diagram of a brain inside a head outline with eyes.

- | | | |
|-------|---|---|
| 3.2 | <p>As the rays of light are reflected off the painting, they enter your eye through the pupil and travel to the back, where they hit the retina, which is the part of the eye that senses light. Embedded in the retina are two types of cells that, because of their appearance, are called cones and rods. Cones are stimulated by bright light and handle color vision, while rods are sensitive to low light, and pick up detail and motion. You can say that cones are sensitive to chrominance (or color), while rods are sensitive to luminance (or the degree of brightness).</p> | <p>Return to painting and person looking at it; rays bouncing off, entering eye, retina. CU of retina with rods and cones.
List attributes under each.</p> <p>Microscopic closeup animation of the retina – cones in different colors, rods in gray. Illuminated as they are discussed.</p> |
| <hr/> | | |
| 3.25 | <p>You can see the distinction between the two by looking at your closet full of clothes in the sunlight, where all the colors are vivid. But let's see what happens when we close the window, and use the slider to slowly turn off the lights. Notice that without the lights on, we can still see the clothes, but the colors become muted and gray. As the slider suggests, this happens because the color-sensitive cones are no longer functioning, while the low-light-capable rods are.</p> | <p>Animation of closet and clothes, open window, window closes, light diminishing, becoming gray.</p> |
| <hr/> | | |
| 3.26 | <p>The difference between rods and cones contributes to other sensibilities our eyes have. Since our perception of color and motion are controlled by two different entities, we aren't able to distinguish color well in objects that are moving. And since rods deal with both luminance and detail, we tend to see details better when they are defined by levels of brightness than by color. That's not to say we won't see details in a color image. But if we were to break down a digital image into its luminance and chrominance values, you can see that we perceive more details in the luminance of the image than in the color information.</p> | <p>Moving color object</p> <p>Color image split into luminance and chrominance</p> |

-
- 3.3 When light hits the retina, a chemical reaction occurs in the rods, which send an electrical impulse that the brain interprets as the level of light (whether light or dark). A similar chemical reaction occurs in the cones. Each cone contains one of three color-sensitive pigments, which roughly respond to red, green or blue light (are you starting to see a pattern here...?) The human eye can see millions of different colors, since red, green and blue can combine to create virtually any color.
- Simulated electrical impulse. CU cones, showing their “pigments”
-
- 3.4 But even when it comes to seeing color, our eyes have limitations. In 1931 an international standards commission determined the range of color that our eyes can see. This is displayed in the CIE Chromaticity Diagram, which was originally produced to allow designers to create specific colors in printing or manufacturing. The two axes represent the hue (or chroma) and the saturation (or intensity) of the color, and the numbers on the figure itself represent the wavelengths of light. Once again notice that the range of what we can see is anchored by red, blue and green, and every other color is a result of combining these three. Also, in the middle, you can see that all lightwave frequencies combined produce white light.
- Chromaticity Diagram
- Emphasis of axes, numbers.
- Arrows pointing to areas as described.
-
- 3.5 You’ll notice that the diagram has a disproportionately large section for green. That’s because the average eye has more green-sensitive cones than other pigments. The eye does an amazing job in compensating for reds and especially blues, but in the end we still see greens better, and have the hardest time distinguishing blues. Have you ever noticed how many shades of green you can see looking into a forest, and yet how hard it is to tell navy blue dress slacks from black ones? The reason is shown there in the diagram. It’s also interesting to note that the number of colors that a computer or television can produce is shown by this triangle in the middle. And the amount that a high-end printer can produce is shown here. Note that your eye
- Arrow pointing to green area.
- Forest and dress slacks
- RGB triangle
- CMYK polygon

can see a greater range of colors than either computers or printers can present.

-
- 3.6 In talking about the human eye, we've mentioned a few limitations or sensitivities it has. We know that:
- We can't see color well in low light.
 - We can't see color well in things that are moving or that change quickly.
 - We don't see much detail in chrominance, or color, but we do in luminance, or the level of brightness.
 - Variations in blue are the least visible to us; and variations in green are the most visible.
- Bullets as they appear.

(Review Questions)

- 4.1 Now that we know all this, what does it mean to the world of digital media? For that discussion, we need to talk about how computers represent and display information.

The most basic piece of information you can find inside a computer is called a bit, which is short for "binary digit." A bit has two states – it's either on, or off, which is also often referred to as being either a one or a zero. All of the information that the computer utilizes is ultimately comprised of bits. This is also true for the computer's representation of color.

Quick zoom inside a computer to reveal a "bit" with an on/off switch. With narration, turns into a 1/0. Multiplies to become a representation of information.

-
- 4.2 When you have one bit, there are two possible options – you can have a 1 or a 0. With two bits, you can have four different combinations. From here, each bit that we add doubles the number of possible states – or the possible information represented. Three bits gives us eight combinations. Four bits gives us sixteen combinations. (For those mathematics fans out there, I'm sure you've realized that the number of combinations is equal to two to the power of how many bits you have). If you have eight bits, that's 256 combinations. And twenty-four bits will give over 16 million. Those numbers might sound familiar to
- A chart develops that show the number of bits and their possible combinations.

you, and we'll talk about why in a minute.

-
- 4.3 When it comes to what the computer shows to us on the screen, I'm sure you know that the most basic unit is called a pixel. The number of pixels you see on your computer screen is determined by the physical resolution of your monitor, that is, the number of horizontal pixels times the number of vertical pixels. Some common resolutions are 640-by-480, 800-by-600, and so forth. If your computer is showing you an image that is 800x600, that image contains 480,000 individual pixels.
- Illustration of computer.
- 640 x 480 pixel areas
800 x 600 pixel areas
1024 x 768 pixel areas
1280 x 1024 pixel areas
- [formula $800 \times 600 = 480,000$]
-
- 4.4 Now don't confuse the display capability of your computer with the size of your monitor. It's possible for even a 14" monitor to have a 1280x1024 pixel resolution, though trying to cram that many pixels on the tiny screen may make things too small to see well. Essentially, the higher the resolution, the more pixels a screen can show, and the more information it can display.
- Comparison of displays and resolution
-
- 5.1 So the number of pixels determines the size and the detail of what you see. But how do they deal with light and color? First, if pixels give off light, what type of color do they use? Right, additive.
- Question: Additive vs. Subtractive
Question: Color options
- (Incorrect feedback: We know they use additive color, because the pixels themselves are emitting the light).*
- And additive color uses what three primary colors? Very good – red, green and blue.
- (Incorrect feedback: Well, additive uses the primary colors of red, green and blue).*
- (Anticipated incorrect feedback: Cyan, magenta and yellow are the primary colors of subtractive color. Additive color use red, green, and blue).*

For a simple explanation of how pixels work, we can say that each pixel on a computer screen is made up of three smaller dots that emit light. The three dots emit the colors red, green and blue, and are so small and close together, that our eyes only perceive the blending of the colors. When none of these dots are glowing, the pixel is black. When all of them are glowing, the pixel appears to be white. When the red and green dots glow at full strength, the pixel appears yellow, and so forth. These colored pixels are then combined to create the image on the screen. So a computer creates color by first combining colored dots within a pixel, and then combining colored pixels on the screen.

Illustration of phosphors, showing colors described, and the reaction on the computer screen.

Pixels creating yellow smiley face

5.2 A few minutes ago we talked about bits and the possible combinations they can create. If we were to assign one bit to each pixel, the pixel could either be on or off. So an image with one bit per pixel, or a 1-bit image, as it's called, would be black and white – no shades of gray, or colors, involved. If we assigned two bits to each pixel it could have four possible colors. Four bits would give us sixteen possible values, and so on. This concept is called bit depth, and it determines how many colors can be represented in an image. Take a moment to look closely at how the bit depth determines the level of detail we perceive in each image.

Previous combination chart

1-bit graphic

2-bit graphic
4-bit graphic

Various bit-depth versions, scroll through them with a radio button.

5.3 Twenty-four bits is probably the most common bit-depth for multimedia development – you'll use it in everything from Photoshop to your favorite video editor. In 24-bit color, 8 bits are allotted to each primary color, so each color can have 256 different shades. This produces 16 million colors, which presents a unique situation. If you think back to the chromaticity diagram, you'll remember that our eyes can see a greater range of color than a computer monitor can produce. But within that range we can only distinguish between 8 million distinct colors. So when 24-bit color provides up to 16 million colors, it's more than our eyes can

8 bit = 256 colors
16 bit = 65,536 colors
24 bit = 16.8 million colors

Illustration of 24-bit division

distinguish.

This is why it's often called true color. You can picture 24-bit color as a set of three sliders, one for each primary color or dot in the pixel. You can move the sliders to 256 different values as you combine the three colors. Give it a try.

(Activity) Sliders and results

5.4 (Omitted)

5.5 Beyond the common 24-bit color, you'll find 32-bit, which is essentially the same as 24, but along with RGB it includes an 8-bit alpha channel, which can be used for things like transparent backgrounds and masking. With some scanners, digital cameras, and applications like Photoshop, as well as in video editing, you'll also find bit depths of 48 and higher. These are often used to accommodate special effects.

Examples of transparent backgrounds

5.6 In the end, the more information that's provided to each pixel, the more faithful the representation of the image will be. More information, however, also means a bigger file size and a higher data rate, which leads to longer download times (if it's on the internet), and a faster computer to be able to work with it (whether it's a still image or video). This is always an issue when working with digital media: quality versus size. There are some processes, however, that help to reduce this problem.

An image with its quality becoming greater and greater, accompanied by the file size, also growing.

(Review Questions)

6.1 There's a lot of information moving around inside a computer, and we know that the less information it has to handle, the more efficiently things run. We talked earlier about the sensitivities and limitations of the human eye. We can use these to our advantage when dealing with digital media by getting rid of the information that our eyes aren't going to detect, and thereby creating smaller, more efficient files that give us what we need for a specific task. Two methods we use to accomplish this are through using different color models, and by creating compression algorithms.

List of sensitivities again.

6.2 When we talk about color models, you should realize that computers don't know

what color is – all they understand are ones and zeros. The raw data that determines the color of pixels for even a simple photograph still amounts to a lot of information. If you were to transfer the image from one computer to another, the image file would have to contain all of that data so that the computer could build the colors from scratch. Color models, however, are kind of the secret decoder ring that allows the computer to process just a few numbers and interpret them into the correct color. If, for example, it receives the numbers 255, 255, 0 for a pixel, and knows that it's using the RGB color model, it can tell that the pixel will show full brightness for red and green, and no brightness for blue (the result will be yellow). Since the computer already knows how to match the numbers with that color model, all we need to do is send the numbers and tell it which color model it's supposed to use. This reduces the amount of data needed to represent a color.

Animation of the “secret decoder ring”, matching numbers to colors

6.3	There are two common color models that you'll come across as you work with digital media: RGB and CMYK.	Names of color models
6.4	You should already have a pretty good idea what RGB is. 256 values are available for each channel of red, green and blue, which are also used in additive color. You'll be using RGB when you prepare graphics for presentation through a computer or on video. Take a minute to look at how the three RGB channels work together to create color.	Illustration of the three channels coming together <i>(Activity) Add or subtract the three channels (layers) to see the results.</i>
6.5	Another common color model is called CMYK, which stands for cyan, magenta, yellow and black (the B was already taken for Blue). CMYK is a subtractive color model, and is used when the image is going to be presented on a subtractive color medium, such as a photograph, or a magazine. It creates colors using the three primaries of cyan, magenta and yellow. When combined, they theoretically create black, but in practice the result is a muddy brown. Black ink is therefore added to make the image more crisp. It's important to realize	Visual explanation of CMYK Venn diagram of colors Computer superimposed over diagram

that when you work with CMYK on the computer, such as in Photoshop, you're actually seeing an RGB interpretation of CMYK, since your monitor only works in RGB. What you see on the screen and what actually prints is often different. Take a look at how CMYK combines to create color.

(Activity) Add or subtract the four channels (layers) of a photograph to see the results.

- 6.6 While RGB and CMYK are the color models you will probably use most frequently, you should be aware that there are many others. These often have specialized uses, such as in graphic design, broadcast television, or video editing.

HSV (graphic design)
YUV (broadcast television)
[YCbCr](#) (component video)

(Review Questions)

- 7.1 Compression schemes are another tool we can use to decrease the amount of information in a media element while maintaining its function. Compression schemes are algorithms, or sets of mathematical steps, that can break down the information for more compact storage, and then put the information back together again, in some form or another. They are often referred to as CODECs, which is short for Compression/Decompression.

Visual derivation of the word CODEC

- 7.2 The complexity of one compression scheme differs from another, but here's a simple example that will help you understand what compression can do. Choose your favorite novel. For me that would be, um, maybe *A Tale a Two Cities*. Let's look at the first part of the first sentence: *It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness...* Let's say I wanted to store this sentence as information. When I count up the number of characters, including spaces, I come up with 108 pieces of information. However, you notice that there is a lot of redundancy in this sentence:

Novel opens and we see first sentence.

Visual counting of the characters

- 7.3
- *it* appears four times
 - *was* appears four times
 - *the* appears four times
 - *of* appears four times
 - *times* appears twice
 - *age* appears twice

Highlight of the words as mentioned

List of word equations

advantage. Many CODECs, like JPEG, store more information about the luminance of the image than about the color, since our eyes are more sensitive to brightness. This allows it to work well with photographic images even though it doesn't keep track of every bit of detail. Also, note how this JPEG places similar colors into square groups. This makes the colors easier for the computer to keep track of, but also weakens the accuracy of the image.

-
- 7.8 As we mentioned before, CODECs aren't limited to still images. You'll also find them in the worlds of digital video and audio. These are similar to still image compression in that they look for patterns of redundant information, and they also offer lossless or lossy options. Video CODECs, however, are especially complex because they deal in three different dimensions. They compress a single frame similar to a still image in what's called spatial compression, since it works within that particular space. But it also looks at how the information changes from one video frame to the next, which is called temporal compression, as it happens over time. This adds a whole new set of issues to control when working with digital video compression, which we'll talk about some other time.
- Display of different media.
- Representation of the information in a single image, which then becomes part of a series of frames.

(Review Questions)

-
- 8.1 Let's take a quick look at the things we've discussed, so you can see how it ties all together.
- (Images and animations that have been used previously)
- We see additive color directly from the light source; we see subtractive color because objects reflect light.
- Light reflecting and light coming directly from the source.
- Our minds perceive color because of the cones in our eyes, which react to red, green and blue light waves. Our eyes are far from perfect, and have certain sensitivities and limitations.
- Diagram of eye and cones.
- The basic unit of information that a computer uses is a bit. The basic
- Animation of bit and pixels.

presentation unit is a pixel, which is made up of red, green and blue dots. Bit depth is the number of bits assigned to each pixel. The greater the bit depth, the larger the file and the data rate for transfer.

Color models are used to make image files more efficient. The computer already understands how the color should be represented, so the image file only needs to contain the numbers that define which color it's using within the model.

RGB and CMYK diagram.

Compression schemes, or CODECs, are also used to make files more efficient. Lossless CODECs compress the information without losing any of it, while lossy CODECs discard information that won't be readily noticed by the human eye. These play on the sensitivities and the limitations of the eye.

Lossy vs. lossless CODECs.

8.2 (Music up) Let's come back to that painting... Doesn't quite look the same, does it? Whether you're designing graphics for the web, or editing digital video footage, you're going to find that these principles serve as a foundation for what you do – and you'll be able to accomplish more if you understand them.

Painting from the intro

Appendix D

Stakeholder Evaluation Questions, Criteria and Standards

Criteria	Question	Evaluation Standard	Data Collection
1. The LIDS lesson should be free from errors or bugs that prevent the user from participating in any aspect of the lesson.	Did the lesson function properly on a technical level?	No errors should be reported by the participating users. When errors are reported, they should be remedied before continuing with the development or evaluation process.	One-on-one sessions, small group questionnaire
2. The LIDS lesson should provide clear instructions on how to navigate the lesson, and the navigation options should fulfill the needs of the user.	Is the LIDS lesson easily navigable?	No navigational difficulties should be reported by the participating users.	One-on-one sessions, small group questionnaire
3. When used by the TMA 271 students, the lesson should stand alone, without technical support, or supplemental support or materials from the instructor.	Did the LIDS lesson function as stand-alone instruction?	When participating in the lesson, the student needed no additional help to use all of its functions and complete the lesson.	One-on-one sessions, small group questionnaire
4. Empirical evidence should support the claim that the students' understanding of LIDS content increased after experiencing the lesson.	Did the lesson aid students in their understanding of LIDS principles?	In using a traditional pre-test/post-test, differences in mean scores will be statistically significant at an alpha level of .05.	Small group pre/post-test
5. Empirical evidence should support the claim that the students'	Did the lesson aid students in their ability to apply LIDS principles to	In using a traditional pre-test/post-test, differences in mean	Small group pre/post-test

ability to apply LIDS principles to practical situations increased after experiencing the lesson.	practical situations?	scores will be statistically significant at an alpha level of .05.	
6. The lesson experienced by the students should be engaging, keep their attention, and give them a personal sense of learning.	Did students feel like the lesson was a worthwhile experience?	Students should reflect this attitude in post-experience questionnaire responses.	Small group questionnaire
7. The students should feel that the various elements added to their learning experience.	Did students think that the various elements (animation, interactivity, questions) were useful in helping them learn?	Students should reflect this attitude in post-experience questionnaire responses.	Small group questionnaire

Appendix E

Pre-test/Post-test

Light in Digital Space

Directions: Complete the following questions in **15 minutes or less**.

1. With respect to computer binary code, if you have four bits, how many possible combinations can they produce?
 - a. 4
 - b. 8
 - c. 16
 - d. 32
 - e. 64

2. What are the primary colors of additive light? Check all that apply.

<input type="checkbox"/> yellow	<input type="checkbox"/> red
<input type="checkbox"/> magenta	<input type="checkbox"/> blue
<input type="checkbox"/> green	<input type="checkbox"/> cyan
<input type="checkbox"/> black	<input type="checkbox"/> white

3. Which one of the following statements best describes the nature of a pixel in a computer monitor? A pixel consists of:
 - a. a single colored light that can change color.
 - b. a colored cube that rotates to display the appropriate color.
 - c. a tiny prism that only lets the appropriate color pass through.
 - d. three colored lights that combine to create the appropriate color.

4. What is the primary function of a CODEC?
 - a. To allow cross-platform usage of media files.
 - b. To create a smaller and more efficient file.
 - c. To create a more secure file by compressing the information.
 - d. To increase the quality of media files through enhancement algorithms.

5. What is one of the greatest advantages of using color models in a computer?
 - a. It restricts the wavelengths of light to only those our eyes can see.
 - b. The color that appears on the monitor is more true to life.
 - c. The information contained in an image or video file is reduced.
 - d. It allows images to be printed with a greater level of detail.

6. Which of the following statements is true? (Circle one or more than one).
 - a. An offset printing press can produce a greater range of colors than the eye can see.
 - b. A high definition monitor can produce a greater range of colors than the eye can see.
 - c. A large format photograph can produce a greater range of colors than the eye can see.
 - d. The human eye can see a greater range of colors than computer monitors can produce.
 - e. The human eye can see a greater range of colors than a laser printer can produce.
 - f. None of the statements above are true.

7. What does the CIE chromaticity diagram tell us about what we can see?

8. You took a photo with a digital camera, and you now want to place the photo on your website. You have very limited server space, so the photo needs to have a small file size, while still maintaining decent quality. Name three aspects of the digital image you can alter to accomplish this, and describe how you would change them.

9. You're waiting for a stoplight at an intersection. The red stoplight is hanging in front of you, and in the lane next to you a yellow school bus comes to a stop. Focusing on the nature of light and its relationship to our eyes, first explain how your eyes can see the color of the stoplight. Then explain how you can see the color of the school bus.

10. Applications are available that will calibrate your monitor, such that what you see on the screen looks like what you print. Why is there often this discrepancy between the colors that you see on your monitor and what comes out of your printer?

11. Our eyes are imperfect – they see some things better than others. Why is this important for you to know when working with digital media?

Appendix F

Questionnaire

Questionnaire: *Light in Digital Space*

Please answer the following questions concerning the *Light in Digital Space* computer-based instructional module. Be honest in your responses, as they will help to improve the effectiveness of the module.

For reference, these are the segments you experienced:

- Introduction – a brief overview of what will be covered.
- Light & Color – nature of light, light’s relationship to color, additive and subtractive color
- Eyes & Color – anatomy of the eye, rods and cones, CIE chromaticity diagram, limitations of the eye
- Bits & Pixels – computer bits, intro to pixels
- Bit Depth – nature of pixels, relationship to bits, bit depth
- Color Models – purpose of color models, RGB, CMYK
- CODECs – nature of CODECs, lossless, lossy, types of CODECs

1. What aspect of the lesson did you like the most? Explain why.

2. What aspect of the lesson did you like the least? Explain why.

3. Did you feel that any particular topic went by too quickly to gain an understanding of it? Which topic(s)?

4. Did you find the questions at the end of each segment helpful in reviewing what you were learning? Explain why or why not.

5. Did you find the interactive activities helpful? Explain why or why not.

6. Did you find the animations helpful in understanding the concepts presented? Explain why or why not.

7. Explain any difficulty you had in navigating the module.

8. Did the lesson have a “professional look and feel” to it? Explain why or why not.

9. Do you feel you learned from the lesson more than you already knew about light in digital space?

10. Would you rather use a computer-based module like this or a traditional textbook as the “text” for this class? Explain your opinion.

11. What suggestions or changes would you make to the lesson to improve it?

Appendix G

Student Questionnaire Responses

Question	Response	Quantity
1. What aspect of the lesson did you like the most? Explain why.	Breadth of information	1
	Interactive examples	8
	Visual interpretations of the principles	4
	Ability to pause, move around the module	1
	Eyes and color section	1
	Use of voice narration	1
	Simple and understandable explanations	1
	The interactive activity of seeing the change in colors	1
2. What aspect of the lesson did you like the least? Explain why.	No aspect of the lesson	2
	Spelling and audio errors	1
	Low quality narration	4
	Having to click on the button to proceed	1
	Bits and Pixels section (I already knew the information)	1
	The essay questions were too broad – I never knew what answer was wanted	1
	Errors in the rods and cones chart	1
	The end-of-segment questions – wording was occasionally vague or confusing	1
3. Did you encounter any technical difficulties or bugs during your experience?	None	9
	There were buttons that didn't link correctly	3
	I wasn't able to see the question boxes	1
	It would only run in Flash Player – not in Explorer	1
4. Did you feel that any particular topic went by too quickly to gain an understanding of it? Which topic(s)?	No	9
	The Bits and Pixels section was too short	1
	The ability to review alleviated the problem	1
	Perhaps the CODEC section	1
	Subtractive light could have been explained better	1
5. Did you find the questions at the end of each segment helpful in reviewing what you were learning? Explain why or why not.	Yes	10
	Sometimes I felt like they were confusing and unrelated	1
	The multiple choice buttons were especially helpful	1
	Yes – a good chance to apply the information	1
	Yes, but I didn't bother answering the essay questions – I just read the answers to make sure I understood it	1
	They were a good review, but poorly worded	1

6. Did you find the interactive activities helpful? Explain why or why not.	Yes	8
	I had learned these principles before, but never in an interactive way	1
	Provided a hands-on experience	2
	Showed instead of told how the concepts worked	2
	Provided a good way to practice the concepts	
	They were nice, but I didn't really need them to understand the concepts	1
		1
	Good chance to apply the concepts	
	They were the key to keeping my attention	1
	Good review of what was just taught	1
	Yes, especially when learning about color	1
	Codecs could have been more interactive	1
	1	
7. Did you find the animations helpful in understanding the concepts presented? Explain why or why not.	Yes	9
	Helped to illustrate the topics	1
	Helped me to focus better on what was being taught	2
	They were helpful, but not necessary to learn the concepts	1
	Yes, I am a visual learner	
	It showed instead of simply told the concepts	3
	1	
8. Explain any difficulty you had in navigating the module.	None	6
	Had a hard time getting started with so many icon choices	1
	I wanted to fast forward or rewind in some sections, not just skip	2
	I didn't like having to click the Forward button	2
	The program froze on the RGB color model demonstration	1
9. Did the lesson have a "professional look and feel to it? Explain why or why not.	Yes	8
	Narrator did not sound professional	5
	Clean and well organized	1
	Simple and easy to navigate	1
10. Do you consider using this lesson more or less effective than reading a chapter in a book? Would you rather use a computer-based module like this or a traditional textbook as the "text" for this class? Explain your opinion.	Computer based training allows interaction that really drives things home	3
	Both – computers are exciting, but after a while it's easy to tune out	1
	Computer-based are more entertaining than a book	1
	Computer modules because they're more interesting and keep my attention	3
	Computer based modules take less time than a textbook, and the information is easier to remember	1
	Computer modules allow the voice to add inflection into the information	1
	Both – there's something nice about words you can see	1
	Computer-based just seem easier to understand	1
	Both – computer for interaction, book for information	1

11. What suggestions or changes would you make to the lesson to improve it?	None – good job	2
	Check for bugs and dead links	3
	Change of narrator	4
	More questions to diagnose comprehension	1
	If you choose a wrong answer, you should be able to review that part in the module	2
	Audio improvement	1
	Clarify the questions a bit more	1

Appendix H

Pre-test/Post-test Scores

Assigned number	Pre-test score (out of 20)	Post-test score (out of 20)
170	13	18
160	8	11
50	6	14
150	9	11
110	1	8
40	10	10
60	9	16
70	6	17
90	5	13
180	6	17
130	7	17
140	12	18
120	8	14
80	4	14
100	7	Non-participant