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Almeria-Mars: A web based robotic simulation

John Travis Ian Wood

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ALMERIA-MARS:
A WEB BASED ROBOTIC SIMULATION

A Project
Presented to the
Faculty of
California State University,
San Bernardino

In Partial Fulfillment
of the Requirements for the Degree
Master of Arts
in
Education:
Instructional Technology

by
John Travis Ian Wood
December 2003
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ABSTRACT

Simulations are an important part in the development of skills and technological advance. They provide a means for developers to test products before they commit to the expense of creating them. And they facilitate the development of skills among those who use expensive equipment, perhaps an F-16 fighter jet. Simulations are prevalent for their distinguishing cost-effective, safe attributes.

This project will discuss the conception of a web-based simulation. In particular, it will deal with the development of a robotic Mars Pathfinder simulation delivered via the World Wide Web. The simulation is comprised of an ROV (constructed with Lego Robotics components, using the RCX computer brick), a web interface (programmed in HTML and JavaScript), and a server (running ports for HTTP, video streaming, and infrared communication with the ROV).
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CHAPTER ONE

INTRODUCTION

Overview

"U.S. pilots who bombed Baghdad say increasingly detailed flight simulators helped familiarize them with the terrain, the threats and even the weather conditions they would face on the battlefield" (Reuters - Washington, 2003).

Simulations are an important part in the development of skills and technological advance. They provide a means for developers to test products before they commit to the expense of creating them. And they facilitate the development of skills among those who use expensive equipment, perhaps a F-16 fighter jet. Simulations are prevalent for their distinguishing cost-effective, safe attributes.

This project will discuss the conception of a web-based simulation. In particular, it will deal with the development of a robotic Mars Pathfinder simulation delivered via the World Wide Web. The simulation is comprised of an ROV (constructed with Lego Robotics components, using the RCX computer brick), a web interface (programmed in Hypertext Markup Language and JavaScript),
and a server (running ports for HTTP, video streaming, and infrared communication with the ROV).

Statement of the Problem

In an attempt to develop more cognitive skills among students, teachers must consider a diversified approach to how they deliver educational content. Knowledge is not something that can be "given" by a teacher to a student. It must be acquired independently through meaningful interaction with materials and information provided by the teacher. Fewer teachers assume there is a "correct" knowledge or a "correct" method of acquisition for students. Students each have unique background knowledge and experiences along with differing learning styles. Awareness of this basic philosophy will ensure that different learning styles are met and concepts are understood. In today's classroom it is certain that employing rote or repetitive conditioning strategies have become passé.

Goals

The aim of this paper is to show how a web-based simulation enunciates popular pedagogical theory, namely a constructivist approach to teaching that fosters critical thinking skills among students. Simulations are a
constructivist’s way of fostering an understanding of complex relationships.

This project will aspire to easily motivate students to construct knowledge about Mars through the collection of data in two ways: 1) by polling real-time sensor data (mathematically adjusted) and 2) by manipulating the ROV to read data from information cards on the colony walls, visible through a camera streaming a real-time video signal. Students will also gain an understanding of the challenges faced by NASA scientists who control the real Pathfinder on Mars to collect data.

When constructing an online robotic simulation it is helpful to consider how the Internet is traditionally and currently used as an educational medium, the characteristics of good website design, and the driving pedagogical theory that best utilizes the unique attributes the Internet and robotics offer to the learning circumstance.

Significance

There are two reasons a teacher will use web-based simulations. One, the teacher will use it to ease instructional demands. Two, the teacher will seize the opportunity to enhance her teaching, and subsequent
learning of her students. But what does it mean to educate a student? Which is the best method? Many teachers are forced to teach to the test because the prevailing wisdom of our system believes that knowledge is simply the gathering and storage of information to be later retrieved, largely because it is measurable. The Internet is a perfect compendium for this job. But teachers cannot bestow knowledge upon those they teach. Knowledge is brought about through meaningful interaction with information gathered. When thinking of knowledge, a teacher may think of Bloom’s Taxonomy. But even it is limited by its one-way hierarchy, one level presupposing the previous. The Internet is a useful tool for gathering information, and disinformation. To sort it all out and make it meaningful, it must go a step further. Teachers must be ever mindful, reflecting on the information presented and gathered via the Internet. They must ask themselves firstly, “What am I getting from this medium of presentation?” “Is my work any easier?” And secondly, “What are my students getting out of it?” Do their interactions inspire authentic learning?

One of the prerequisites of building knowledge for a student is her active involvement in the process of learning. Generating interest among students is time
consuming for teachers who meet the challenge. With the increasing number of concepts teachers are faced with delivering, a more efficient means of reaching higher level thinking skills is crucial.

Limitation

Constructivism is the process of building meaning from our experiences. And a simulation certainly allows students to construct meaning from the individual interaction they have. However, a social constructivist may claim a shortcoming of collaboration in realized learning. For her, collaboration is a key element in learning constructively within the social constructivist paradigm. This is not an absent characteristic. A chat window is available to ROV operators. The limitation lies with the facilitator's use of the chat server to promote a cooperative effort in reaching for learning objectives. This is not a significant limitation of the project itself. It is a limitation of its effective use, changing with the dynamic nature of technology and those who use it.

Computers with Internet access are a constraint for some students. However, Web connectivity and computers are becoming more plentiful as the years progress. For
example, who of us face the inability to access a telephone to communicate with others? Again, this is another limitation that does not significantly impede the goal of this project.

More appreciable limitations are within the constraints faced by teachers, namely that "simulation use is often teacher intensive, with students requiring guidance in their use and support and expertise to interpret results or handle queries. Technical difficulties, expense of production and the need for learner support have all contributed to a lack of use of simulations in on-line and distance learning" (Ruth Thomas, 2000, p. 7).

Definition of Terms

ROV - Remotely Operated Vehicle.

JavaScript - A scripting language developed by Netscape and used to create interactive Web sites.

Dreamweaver - An HTML editing program sold by Macromedia Corporation.

NQC (Not Quite C) - A "C"-like programming language developed by David Baum for the Lego programmable RCX brick.
**HTML** (Hyper Text Markup Language) - a set of special codes referred to as "tags," which instruct a web browser how to display a hypertext document.

**RCX** - A programmable, microcontroller-based brick that can simultaneously operate three motors, three sensors, and an infrared serial communications interface.

**TI** - a telecommunications industry term for a data connection at 1.544 Megabits per second.

**Index page/default page** - the default HTML webpage that loads within a web domain’s public folder.

**HTTP** (Hypertext Transfer Protocol) - the World Wide Web application protocol that runs on top of the Internet's TCP/IP protocol.

**TCP Port** - Data transmitted over a network using the Transport Control Protocol/Internet Protocol (TCP/IP), such as the Internet, includes address information that identifies the computer (32-bit IP address) and a port.

**Router** - A device that links a local network to a remote network.

**Firewall** - a combination of hardware and software that protects computer networks.
LAN (Local Area Network) - is a computer network (or data communications network) which is confined in a limited geographical area.

WAN (Wide Area Network) - A computer network which spans great distances. Usually connects many LANs together.

DNS (Domain Name Server) - The Domain Naming System maps IP addresses to names and vice-versa.

IP - a specified format of packets, also called datagrams, and the addressing scheme that identifies computers using Transport Control Protocol.

Domain name - A name that identifies one or more IP addresses. For example, the domain name microsoft.com represents about a dozen IP addresses.

Spirit.ocx - the OLE Control Extension module created by Lego that can be accessed by other programs in a Windows environment.

FTP (File Transfer Protocol) - the protocol used on the Internet for exchanging files.
CHAPTER TWO
REVIEW OF THE LITERATURE

Social Constructivism

When it comes to a belief about how to use the Internet to teach, it seems the Internet has something for everyone, eclectically drawing what you need. Learning can be individual or social. Educators extract from a continuum where objectivism lies at one end, and constructivism lies at the other (Tillman, 1998). Thereby a teacher may be an objectivist, delivering a traditional lecture. Or she may be a constructivist, facilitating, observing, and coaching.

Simulations are fashionable among constructivists for two reasons. Firstly, within a simulation, the learner is free to explore and experiment without hindrance in a realistic environment. Secondly, they are popular for the immediate outcome resulting from a learner’s interactivity.

From a constructivist view, the teacher does not take the active role in learning, the student does. The student is cognitively active in the construction of knowledge and meaning. The teacher is a facilitator of "authentic, holistic, long-term, divergent, constructive, and social"
activities, and does not dispense knowledge (Kitsantas, Baylor, & Hu, 2001). The constructivist also holds much solace in the community’s ability to scaffold learning: For it “occurs most effectively within communities that have developed trust, shared understanding of problems, and a language to communicate problems” (Pang & Hung, 2001, p. 40). The Internet can be a social venture that spans time and geography, supporting learning as a social act. Vygotsky considers social collaboration with others paramount when creating zones of proximal development. Only through the development of these zones can a student progress beyond their current level of understanding (Pang & Hung, 2001).

There are three interpretations of constructivism according to Moshman (1982). Endogenous constructivism relies solely on the learner. The teacher acts only as a facilitator, providing challenging experiences for the student’s existing models. Most simulations fall within this construal. Exogenous constructivism relies on the teacher to provide direct instruction with students cognitively active, constructing knowledge of their own. The social constructivist would likely favour dialectical constructivism. For it relies on interaction between learners, peers, and teachers.
To the social constructivist, online community development is essential to social success on the web. Personalization engines gather information about Internet users for the purpose of matching their characteristics. They make use of cookies, small text files created on a user's computer by web sites. These files store information that personally identifies each user. Virtual communities are subsequently built based on profiles that are sorted through complex mathematical algorithms. These "collaborative filters," as they are called, connect people with similar profiles (Hung & Nichani, 2001). Hung (2001) argues that many students feel uncomfortable asking peers face-to-face for help when faced with problems of understanding. And the online community is a suitable venue for confronting those problems. The computer does not make the student feel uncomfortable when she takes risks and fails. The student is easily motivated to try again, creating a lure of mastery that becomes seductive to her (Kuriloff, 2000). Computer enthusiasts, in fact, take learning into their own hands, "learning by doing" as Dewey says. Dewey also stressed that the educational value of learning experiences are not equivalent to one another, the largest weakness the Internet has to offer. There is a vast amount of information on the web. But none of it will
represent a good education without someone guiding students through the analysis and critical reflection necessary to reach thoughtful conclusions (Kuriloff, 2000).

Bloom's Taxonomy - Not Just Critical Thinking

Critical thinking is comprised of elements such as: observations, facts, inferences, assumptions, opinions, arguments, critical analysis, and so on. To understand this it to discern Bloom's Taxonomy of Educational Objectives as contributing criteria that experts in the field accept as a measure for higher-level thinking within the aforementioned elements. After all, critical thinking predates Bloom, excluding Socrates, with the work of Glaser's An Experiment in the Development of Critical Thinking (Glaser, 1941). The critical thinking movement "makes use of" Bloom's levels of the cognitive domain because it, for the most part, nicely epitomizes what critical thinking represents. Bloom's Taxonomy of Educational Objectives (Cognitive Domain) was "not designed to further critical thinking [but] contains a wealth of information of use in its instruction" (Paul, 1995, p. 221). Critical thinking "is a systematic way to form and shape one's thinking. It functions purposefully
and exactlying. It is thought that it is disciplined, comprehensive, based on intellectual standards, and as a result, well reasoned" (Willsen, 1995, p. 18). Bloom's levels in the Cognitive Domain are widely accepted as the intellectual standards that govern the elements of critical thinking, but don't represent critical thinking itself.

A widespread belief with teachers is that education should develop a student's cognitive ability. But the discerning teacher knows there are equally important areas of development students require: intellectual development is only part of the equation. Hence why, Benjamin Bloom accounts for more than cognitive development in his taxonomy. In addition to the Cognitive Domain, he includes the Affective Domain (growth in emotional areas - attitude) and Psychomotor Domain (growth in manual or physical skills).

How does simulation fit within the cognitive domain? For the participant it promotes analytical thinking, sharpening "his skills of analysis, making judgments, and experiencing the immediate consequences of them". This may include the ability to:

- Separate relevant from irrelevant
- Identify assumptions
• Separate fact and opinion
• Set realistic goals
• Establish priorities

Within the Affective Domain, participants gain insight into their own behaviour, developing sensitivity to perceptions as they interact with others (Parry, 1971). Intrinsic motivation and jurisdiction choices also lend to improved attitudes. And lastly, within the Psychomotor Domain, participants refine sensory cues to guide motor activity, skills such as hand-eye coordination. There are two popular models of this domain:

Dave’s model (Dave, 1970):

• Imitation: Observing and patterning behavior after someone else. Performance may be of low quality. Example: Copying a work of art.

• Manipulation: Being able to perform certain actions by following instructions and practicing. Example: Creating work on one’s own, after taking lessons, or reading about it.

• Precision: Refining, becoming more exact. Few errors are apparent. Example: Working and reworking something, so it will be “just right.”
• Articulation: Coordinating a series of actions, achieving harmony and internal consistency. Example: Producing a video that involves music, drama, color, sound, etc.

• Naturalization: Having high-level performance become natural, without needing to think much about it. Examples: Michael Jordan playing basketball, Nancy And Harrow’s model:
  • Involuntary movement - reaction
  • Fundamental movements - basic movements
  • Perception - response to stimuli
  • Physical abilities - stamina that must be developed for further development
  • Skilled movements - advanced learned movements
  • No discursive communication - effective body language

Simulations accommodate all three types of learning set forth by Benjamin Bloom’s learning domains.

Simulations

What is a simulation? A simulation can be anything that attempts to emulate real-life circumstances and events, or “a set of rules which creates a simplified model of reality” (Alder et al., 2001, p. 347). It could
be a board game such as Monopoly that models the circumstances and events of a real estate environment.

According to Alder et al, when students use simulations, they "become very involved in the subject while playing them...stimulating genuine student interest" (Alder et al., 2001, p. 345). Learners are active participants. And while actively involved, they are enticed to make choices. The control over decision-making is motivating.

For the most part, pre-Internet computer simulations lacked the prospect of interacting in a social context. They were largely designed for the purpose of training the user how to use perform a specific task or for testing hypotheses in research. The Internet has brought about the possibility for programmers to add social constructs.

Web-based simulations have an advantage over traditional simulations that fall within Moshan’s first constructivist interpretation, endogenous constructivism. Now with the advent of the Internet, simulations would conceivably fit within Moshman’s last interpretation of constructivism, dialectical constructivism. Many online simulations fulfill the characteristics of dialectical constructivism, social interaction and collaborative problem solving. Take for instance the simulation game...
WarCraft by Blizzard Entertainment. WarCraft is a game where participants role-play in a fantasy simulation. As is true in real life, variables make unpredictable circumstances that, once dealt with, result in immediate responses. In this simulation, programmers constantly change the environment from month to month online, reproducing life-like variations. Once a player has joined the online community, they may build alliances to compete with others. The online community numbers in the thousands.

The user may play the simulation without connecting to the Internet. In which case, the game falls within the confines of Moshman's first interpretation of constructivism, endogenous constructivism. However when the player connects to the Internet, there are opportunities to join with others, consolidating strategies to defeat other armies. Players contribute and collaborate to construct strategy and solve problems, clearly dialectical constructivism.

Additionally, simulations free learners of the constraints faced by real-world events. Students are able to manipulate data they would otherwise be unable to collect themselves, data perhaps from a probe sent to another planet. They are unencumbered by restrictions of
travel to places like Yellowstone National Park or the planet from which the data came from. Resources necessary for real-life ventures are waived in favour of simulation. Students dissecting frogs do not need a scalpel, tray, pins, scissors, or the frog itself. For that matter, the teacher is more comforted with the fact scalpels are out of the hands of some students. Students are also able to revisit parts of their lesson, doing it over and over again as they please.

The Internet in Education

To understand educational delivery via the web, a brief history of the Internet is helpful. The idea was kernelled when Bush described his theory of storing and retrieving information on machines in 1945. In 1965, Nelson coined the term hypertext, as a means of describing non-linear (linked) text. But the infrastructure for these theoretical exchanges of information didn’t occur until 1969 when Arpanet established their network of computers, designed to withstand military attack. The year 1982 saw the term “Internet” first recorded. But it wasn’t until the Internet was opened to commercial use in 1991 that it started to jockey for public communication. By 1997 there were over 16 million Internet hosts, which almost doubled
by 1998 (Kohnen, 1998). Today, one would be hard pressed to find someone who didn’t know what the Internet was.

The Internet is to education today as the motion picture was to education in Edison’s time. It has the potential to move education a giant step forward. But with the advent of any technology, there are those who question it. Some legitimately question how it is used as an educational tool. And some question it because they lack understanding of the technology. Developments in communication have always been received with mixed feelings. Plato was concerned that written material would compromise the development of a person’s memory. And Neil Postman believed that for every gain brought with a new technology something is sacrificed (Withrow, 1997).

Internet delivery of educational material cannot replace all learning (at least not yet). There are four models of instruction commonly used for Internet instruction. The first is when the technology is the curriculum. In this model, technology is the focus and not learned in context. The second model occurs when the Internet is the delivery mechanism. Learners use the technology for a single purpose, perhaps to learn a concept in math. When a teacher uses the Internet to complement her instruction, the third model of instruction
is employed: She will supplement her lessons with traditional instruction. The last model is when the Internet disappears from a learner’s scrutiny, as a chalkboard does during a traditional lesson (Imel & Wagner, 1998).

Understanding is best achieved when concepts and skills are learned in context, reflecting the real world. Student motivation is best achieved when communities of collaborative students cooperate and support one another (Ryder & Hughes, 1985). The Internet is a superb medium to fulfill our “inherent social need to deliver, ever more quickly and accurately, our experience and knowledge” (Withrow, 1997, p. 60).

Internet learning is not for everybody, or every situation. Today it is used to deliver academic content and simulations. The charm is in the interactivity of multimedia: audio, video, and graphics. This is practical for the military when training pilots, soldiers, and sailors to operate sophisticated and dangerous weapon systems. It falters, however, when social contact is necessary. The “soft skills” (leadership, communication, customer relations, supervision) for instance are best modeled through human interaction. And to date, there are
no welders graduating from online institutions (Kearsley, 2002).

Website Design

Currently there are no standards that govern design criteria for Web site publishing. Conventions used in publishing books evolved over centuries and were largely necessary because of the expense and time it took to publish a book (Maddux, 1998). Today, a Web page can be published quickly and with little or no expense. And the quality of Web pages is not improving, but deteriorating. The vast number of people publishing to the Web with ease is the most likely reason for this decline of quality (Maddux, 1998). Finding sites that offer well-organized and useful content will then become increasingly difficult. Maddux suggests the following tips:

1. Always use Meta tags. This will supply more specific information for search engines that will, in turn, categorize the website more specifically.

2. Always provide the name of the author, sponsor, and professional qualities of the author. This will not only help search engines categorize the
page but will assist the viewer if the page is a subset of what she is looking for.

3. Always provide a link to the home page. Many times search engines will send a client to a page nested among others with no clear links to related pages. It is appropriate to start at the beginning, the home page.

4. Always provide page titles. There are two titles to include, one at the top of the page and another embedded in the HTML. The second is necessary if the title is to be displayed on a search engine.

5. Always describe the purpose of the page. A brief and concise paragraph will aid the visitor in deciding whether or not the information sought is present.

6. Avoid the use of frames. There are still many browsers that don’t support frames. If frames are used, then a second, alternative, page should also be constructed for those who dislike frames or their browser is not capable of supporting frames.

7. Avoid publishing pages that are "Under Construction." There are too many of these pages
that only serve to clutter the Web and the indexing of them on search engines.

8. Carefully check language and mechanics. Publishing pages riddled with grammatical or structural deficiencies will only propagate those deficiencies to others, or leave the impression that the publisher is careless or illiterate.

9. Make sure pages are up-to-date. A visitor should view a page that has current information and unbroken links to other pages (Maddox, 1998). Booher and Wilcox (2001) provide several of the same tips, with some additional:

1. Organize the information. Creating a flow chart, placing information in levels of importance separates basic information from general information.

2. Research other websites. The goal is to fish for ideas from other examples.

3. Provide easy navigation. The pages should be "user friendly". They should download quickly, appeal to the visitor graphically, and be easy to maneuver.
4. Revisit, revise, and rework. Before a website is posted, it should be tested and peer reviewed (Booher & Wilcox, 2001). A site should invite the visitor back with the promise of fresh content.

When planning a site Ruffini (2001) says that 5" x 8" index cards provide a means of structuring and simulating information presented and collected. He suggests these four design structures to consider.

1. A sequential structure gathers and organizes information sequentially in order from general to specific, alphabetical order, or chronological order.

2. A grid structure maintains no order of importance. It organizes information based on interrelationships between topics.

3. A hierarchical structure employs the standard home page and arranges information into topics and subtopics in order of importance.

4. A Web structure uses a free flowing, non-structured navigation. The user explores links autonomously and must recognize interrelationships between topics to easily navigate (Ruffini, 2001).
He further suggests these design principles.

1. The simplicity principle allows the website to communicate efficiently, conveying one idea. If there are multiple ideas, they should be delivered one at a time in a series of visuals to maximize the visitor's comprehension.

2. Emphasis is a way of drawing the visitor's attention to important elements of the Web page. Contrasting colors, arrows, labels, or changing the font size can accomplish this.

3. Balance is a means of appealing to visitors, visually. The two types of balance are formal and informal. Formal balance occurs when information in halves is presented symmetrically and centered vertically. Informal balance occurs when arrangement is not symmetrical but appears balanced and stable.

4. Unity is achieved when the relationship between elements is strong. Suggestions for accomplishing this are to place elements close to one another, overlap them, or use borders and background shapes (Ruffini, 2001).

The homepage is like the lobby of a hotel, where the concierge greets visitors and offers relevant information.
sought. The top four inches of a homepage is the most effective space for capturing the interest of visitors: For they are accustomed to evaluating the value of a page at first glance. Any given page should be no longer than two screens long. Surfers are habituated by the concise “chunks” of information used to compensate for the fact that it takes 25% longer to read from a monitor than paper (Ruffini, 2001).

Ruffini asserts that serif and sans serif should be considered as a guideline for text design. Serif fonts (e.g. Times New Roman, Georgia) are best for the body of the text because they are easier to read for extended periods of time, with their beginning or finishing strokes on each letter. Sans Serif fonts (e.g. Arial, Verdana) have no strokes and are well suited for titles, headers, and labels because they are easily recognizable and provide some contrast. Contrast within the body text can occur in strategically placed bold or italicized text. But be warned that underlined and coloured text can be confused with hyperlinks. And capitalizing text is a common, and least effective, way to add typographical emphasis.

When choosing a graphics format, the common choice is between GIF (Graphics Interchange Format) and JPEG (Joint
Photographic Experts Group). Each has a rationale for selection. GIF would be a suitable candidate if a graphic has large areas of homogeneous colour and is limited to 8-bit colour (256 or fewer colours). JPEG is a candidate if it is necessary to display the graphic in "true colour" (24-bit, millions of colours). JPEG typically has better compression than GIF but does not have the interlacing advantage that GIF images have. With the interlacing feature of GIF images, one can combine multiple images to create animations or eliminate the alpha channel, removing the background colour (Ruffini, 2001).

A website should be goal oriented with a clear message for surfers. The target audience must be identified and presented with relevant content that is quickly accessible, maintaining interest. And in the end, "it's not what you think about your site that counts. It's what users think about it" (Goldsborough, 2001, p. 16).
CHAPTER THREE

METHODOLOGY

Analysis

Because the simulation is targeted at a middle school audience, middle school students appropriately provided information about its effective use. An attempt to select a variety of students with differences in gender and educational success reflect a diverse population for this project. Presumably, the greater variety of responses; the better the resulting feedback.

For the purpose of this analysis, grade seven students from three core groups of math classes were used. Using a stratified random model, five students were selected from each group. Of the three groups, two are lower academic performing RSP (Resource Student Program) students; and one group is comprised of higher academic performing GATE (Gifted and Talented Education) students. A PC computer with Internet Explorer 5.01 and a T1 Internet connection was utilized for the evaluation. Students were asked to first complete the tutorial and then operate the ROV to collect various data to answer the online mission quiz (see Appendix A).
Data was collected by means of observation, interview questions and a survey instrument (see Appendix B). Using a contextual enquiry technique, each subject was observed, noting:

- Facial expressions
- Commentary while engaged in the activity
- The average time to find each answer
- The average time to complete the tutorial
- Success rate
- Help needed
- Areas of difficulty (errors)
- Attitude while engaged in the activity

Upon completing the activity each student was asked to complete a survey form, evaluating the most common heuristics: navigation, graphics, functionality, control, and visual clarity. Additional interview questions revealed background about the student's use of computers and the Internet, as well as open-ended responses about how to improve the simulation.

To gain direction for a design, a basic web page adorned with only rudimentary controls necessary for operating the ROV was used to conduct a survey (see Figure 1). Participants were asked to pilot the ROV for
five minutes while giving thought to features, maneuverability, and design. The following questions asked included:

- How do you find the look of the control panel?
- What would you change?
- If you were to add any features to the controls, what would they be?
- Was the control panel responsive to commands? Did the ROV move as anticipated?
- Was the video image adequate to allow you to see where you were going?
- Do you have a computer in your home?
- How often do you use a computer?
- Do you have Internet in your home?
- How often do you access the Internet?

The resulting data was utilized to simply guide the development of a revised simulation that appeals to all the attributes of the project identified as making the simulation an enjoyable and educational activity.
Figure 1. Prototype Control Interface

Design

Those surveyed claimed the control panel page was much too plain, having little visual appeal. Many suggested a control panel that resembled one commonly found in newer Star Trek episodes. There were none that found the controls unresponsive. The ROV moved as they expected. Several asked if real-time sensor data was possible, also tied to the control panel. And there were no issues with the video signal streaming from the ROV’s
camera. However, a popular complaint was the lack of visual perspective when docking or maneuvering to view the data cards on colony walls. The ROV occasionally became hung up on obstacles. Students suggested that a birds-eye view of the colony would help them avoid encumbrances.

Development

Survey responses led the direction of modifications. The control panel was the first to be altered. But to accomplish the visual appeal of a Star Trek control panel it was necessary to create an image of the panel in a paint program. It was fashioned in several pieces and laid into a Dreamweaver HTML document in layers. After the layout was finalized, the layers were converted to a table to decrease loading time. The controls are image maps that call subroutines on the robot through JavaScript (see Figure 2).

A newer version of the RCX server software accommodated polled sensor data from the RCX computer, presenting an opportune time to add sensor buttons to the new control panel. To combat the lack of visual perspective participants claimed an additional camera was installed overhead to offer better viewpoints of objects and the distances between them.
Figure 2. Control Interface Based on Usability Survey Feedback

**Tutorial**

Although not part of the formal survey, a tutorial was created using Authorware 6. Students using it are required to download the respective plug-in from the Macromedia website. The tutorial is meant to familiarize students with the controls that manipulate the rover and poll its computer for sensor information. Without this familiarity, students are drawn away from the objective of the activity, namely reading the data information on
colony walls, because their focus is on learning the controls.

Website

The domain http://www.MarsROV.com was purchased to present the index, or default, page of the website. The pages residing on this site were programmed with HTML and JavaScript to bring up properly sized windows when links were clicked and pass on commands to respective server software installed on the ROV server.

Remotely Operated Vehicle

It was not feasible to use the native object oriented language supplied by Lego to program the ROV. It lacks the ability to interface with web-based programming languages. NQC, a C-like language, was selected to program the ROV because it easily interfaces with JavaScript. David Baum who has published two books about Lego robotics, Definitive Guide to LEGO MINDSTORMS and Extreme Mindstorms an Advanced Guide to LEGO MINDSTORMS, developed NQC.

Colony

The Mars-like colony was constructed from a four by eight sheet of ¼ inch plywood. Mixing red paint with a drywall stippling material, common with most household
ceilings, created the surface. A brown spray paint augmented the red colour for variation. The form of the mountain was shaped with chicken wire and covered with paper mache. Reminiscent of Mount Rushmore, the mountain features three faces: E.T., Yoda, and an alien Grey. They were molded from self-dying clay. The docking ramp, like the ROV, was constructed from Lego.

Implementation

There are four requisite software components for this project. They are: 1) web server software, 2) RCX server software, 3) streaming video server software, and 4) FTP upload software (specifically designed for uploading web cam images). The software necessary to run this simulation dictates the use of a PC compatible computer. It will not run on an Apple computer. A dedicated web server is recommended.

Web Server

Web server software must be setup to accept HTTP requests on port 80. If the server is part of an internal LAN, there is likely a router and firewall handling HTTP requests between the Internet and LAN. To understand this better, analogy to a hotel is useful. You may consider the router as the doorway to a hotel and the firewall as the
concierge that determines who gets into the building. If this is the case, contacting the network administrator is necessary. And two requests must be made of the administrator to complete the setup for the WWW/ROV server. The first is for an entry in the DNS table of the WAN router. This will resolve a domain name with the IP address of the WWW/ROV server. For example, the name of the Almeria-Mars Pathfinder server, http://almeriams.fusd.net, resolves to the internal IP address of 10.31.10.11. Therefore almeriams was added to the router that resolves all fusd.net HTTP requests. The second request is to ask for three open ports through the firewall. Port 80 is necessary for HTTP requests to reach your web server software. Port 8888 is commonly used for video streaming server software. And port 7070 is used to communicate with the RCX server software. Though this is not always possible, for good reason. When a network administrator opens a port through a firewall it greatly increases the opportunities for hackers to infiltrate the internal LAN.

RCX server software, running on port 7070, communicates with the RCX through an infrared tower. There are two RCX servers available as freeware: WebRCX (Ireland, 2002) and WebBrick (Silverstein, 2002). These
server programs handle commands made via JavaScript embedded in HTML documents. They pass on the commands through spirit.ocx to the infrared tower that, in turn, communicates with the RCX computer on the ROV.

Video signals are handled by two remaining pieces of software. Webcam32 is a video streaming software that responds to HTTP requests on port 8888. It provides a real-time video stream that is limited only by the connection speed between computers. Ispy is a program that simply uploads a captured image via FTP at a set interval. The uploaded image is refreshed by the HTML code in the viewing web page.

Evaluation

The formative evaluation of the Almeria-Mars Pathfinder simulation attempted to reveal issues of efficiency, effectiveness, and satisfaction within the activity.

The GATE students were the first group studied. All five students were comfortable while using the simulation. This was evident in a number of ways. None of the students appeared to have frustrated facial expressions. There were no errors. They needed no help. There was little commentary. They found the answers and completed the
Table 1. Usability Survey Results

<table>
<thead>
<tr>
<th>Description / Identification of Survey Item</th>
<th>Mean Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tutorial / Simulation</td>
<td>Group 1</td>
</tr>
<tr>
<td>1. Ease of use</td>
<td>5</td>
</tr>
<tr>
<td>2. Look &amp; Feel</td>
<td>5</td>
</tr>
<tr>
<td>3. Navigation</td>
<td>4.8</td>
</tr>
<tr>
<td>4. Graphics</td>
<td>5</td>
</tr>
<tr>
<td>5. Overall</td>
<td>5</td>
</tr>
<tr>
<td>Quiz</td>
<td>Group 1</td>
</tr>
<tr>
<td>1. Ease of use</td>
<td>4.6</td>
</tr>
<tr>
<td>2. Look &amp; Feel</td>
<td>5</td>
</tr>
<tr>
<td>3. Navigation</td>
<td>4.8</td>
</tr>
<tr>
<td>4. Graphics</td>
<td>5</td>
</tr>
<tr>
<td>5. Overall</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Simulation expeditiously. And they expressed a positive attitude about the activity. The only weakness uncovered was an overlapping font, obscuring the tutorial navigation buttons. It is important to note that all students have computers at home and they navigate the Internet regularly. The only suggestion for improving the simulation was to correct the overlaying font in the tutorial. No difficulty was reported in the operation of the ROV.

RSP students comprised the remaining two groups studied. Initially, several students made note that the phrase "press continue to start your training" remained
among the instructions after the continue button had been replaced by "quiz" and "exit" buttons of the tutorial. This confused many of the RSP students, maintaining a literal view of the text remaining. The GATE students overlooked it, inferring that the text no longer applied once they chose the "continue" button. The RSP students also experienced more difficulty navigating through the quiz part of the tutorial than the GATE students. This occurred when they made errors and clicked on the "previous" button. They attempted to correct their answers. However, once the previous button was selected, the tutorial would not allow the user to choose another answer. They were forced to move onto the next question without the option for a second attempt. The only suggestions for improving the tutorial from RSP students was to erase the contradicting text in the introduction and fix the user's ability to attempt to answer a question if the previous button was selected. Again, operation of the ROV was unfettered.

Only one of the ten RSP students had a computer at home. And two of the ten navigated the Internet daily. The differences between the two groups illustrated a relationship, namely between their success using the
simulation and their previous use of the Internet and computers.
When creating a web-based simulation with Lego Robotics, one must consider many aspects of its construction. Adhering to the principles of good web design will make certain that users are not distracted from the purpose of the simulation, while offering the visual appeal necessary to motivate its use. Choices for programming the RCX computer module dictate the resulting interface and whether it is locally hosted or delivered via the Internet. The conscious-driven creator, however, deliberates over how the simulation uses learning theory to compliment the technology used. For she knows that authentic learning comes from the intrinsic motivation of an active participant, generated by sincere interest in the activity. Further to this point, an educationally worthy simulation accomplishes a clear learning objective by expeditiously building meaning and understanding of concepts in a social constructivist environment, removing the influence of the teacher. The result is a student who develops more than just the intellectual skills of Bloom's Cognitive Domain but also skills in the Affective, and
Psychomotor Domain. Recalling a science methodology class, there was a saying. I hear: And I forget. I see: And I remember. I do: And I understand. I think: And I make it my own. Simulations encompass this saying whilst reflecting the most recent learning pedagogy. They appeal to learners in a manner that effectively facilitates "thinking" and genuine learning.

Recommendations

Those considering the use of simulation to teach students should feel compelled to ask the following questions:

1. What do I want students to learn?

2. How do I want students to learn?
   a. What pedagogy will I exploit?
   b. What educational strategies can I take advantage of?
   c. What technology is suitable to draw out a given pedagogy?

3. What do I need to create a web-based simulation?
   a. What programming medium is the most appropriate for the task?
   b. What programs will I need?
4. What information will students need before the activity?

5. How will I evaluate the success of the activity?

Those creating simulations should be specific, narrowing the focus of educational objectives. Its importance lies in giving the simulation purpose. Without it, time is frittered away by student and creator. The purpose should be evident to the student. And the technology driving the simulation should be seamless, obscured by the activity itself.

Simulations ought to make conscious use of suitable pedagogy and educational strategies to get the most out of the technology employed. Again, this enunciates a simulation’s purpose to educate the user. A question posed such as “what technology can I use to develop the student’s zone of proximal development?” is fitting. The answer may be a discussion board, used to dialogue and compare simulated experiences. As well, educational strategies that draw on a user’s psychological conditioning also beg consideration. For instance, the appeal of a visual reward, perhaps an accumulation of golden stars, may motivate continued use.

The inceptions of such web-based projects are influenced by the previous experience of those involved
and resources at hand. When programming for delivery via the Internet, there are many ways to construct a simulation's interface, each specific to a task. For instance, if a simulation relies heavily on a database, programming with PHP language that utilizes a MySQL relational database is an astute preference. The tasks of a simulation should therefore meet the competence of the presenting medium. The same applies to supporting applications chosen. Choices must reflect the obligations of the simulation's functions. Because interaction with the user is necessary, it is certain that programmers must use dynamic pages. Dynamic content can be delivered using a number of web delivery technologies. Examples of dynamic programming languages include Active Server Pages (ASP), Hypertext Preprocessor pages (PHP), Cold Fusion paged (CFM), and Java Server Pages (JSP). The Internet offers a vast depository of resources to learn more about these languages.

To ensure that the focus is on not on learning how to navigate the simulation, users should receive preparatory information. A tutorial centered on directing the user along a clear path toward an equally clear expectation best achieves this. Macromedia Authorware is only one
application that can provide a means of delivering a tutorial using the Internet.

A simulation worthy of use is one that accomplishes a clear learning objective and develops a student's thinking. Evaluating a simulation is important to the development of this venture. Further to this point, not only should the simulation be evaluated but also the resulting learning that occurs.
APPENDIX A

ALMERIA-MARS MISSION QUIZ
Almeria-Mars Mission Quiz
Mr. Travis Wood, Almeria Middle School (Fontana, CA)
Answer the questions below and then click “submit” to send your answers.

1. Which is not an adaptation astronauts make to accommodate weightlessness.
   Your answer:
   ○ Wearing magnetic boots
   ○ Wearing a seatbelt when sleeping
   ○ Sleeping against a wall
   ○ Taking sponge baths

2. How long can a person survive unprotected in outer space?
   Your answer:
   ○ 2 hours
   ○ 15 seconds
   ○ 25 minutes
   ○ 5 minutes

3. How long will the footprints left on Earth’s moon by astronauts likely remain?
   Your answer:
   ○ Over 1000 years
   ○ Over 1 million years
   ○ Over 100 years
   ○ Over 500 years
4. Which planet in our solar system is the hottest?

Your answer:

5. How many galaxies do astronomers estimate there are in the universe?

Your answer:
- 100 billion
- Thousands
- Tens of thousands
- Millions

6. Name one of the asteroids in our solar system's asteroid belt.

Your answer:

7. How long (earth time) is a day on Mercury?

Your answer:
- Over a month
- Over a year
- Over 2 years
- Over a week

8. Saturn's rings are made up of billions of pieces of?

Your answer:
9. The sun will one day grow large enough to swallow up many planets, including Earth.

Your answer:
- True
- False

10. Name a telescope orbiting the earth.

Your answer:
- Einstein
- Pegasus
- Phoenix
- Hubble
APPENDIX B

SURVEY INSTRUMENT
Usability Evaluation – Almeria-Mars Pathfinder Control Tutorial

Age/ Grade Level: ________________________________
Gender: ________________________________

1 Poor 2 Fair 3 Good 4 Very Good 5 Excellent

For each item identified below, circle the number to the right that best fits your judgment of its quality. Use the scale above to select the quality number.

<table>
<thead>
<tr>
<th>Description / Identification of Survey Item</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tutorial</strong></td>
<td></td>
</tr>
<tr>
<td>1. Ease of use</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2. Look &amp; Feel</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3. Navigation</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>4. Graphics</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>5. Overall</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td><strong>Quiz</strong></td>
<td></td>
</tr>
<tr>
<td>1. Ease of use</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>2. Look &amp; Feel</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>3. Navigation</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>4. Graphics</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>5. Overall</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

Interview Questions:

1. How often do you use the Internet?
   - Daily
   - Weekly
   - Monthly
   - Never

2. Do you have a computer at home?
   - Yes
   - No

3. What would make the tutorial easier for you to use?
APPENDIX C

CONTROL PANEL: USERNAME AND PASSWORD
Pathfinder Control Panel

Username: almeria

Password: pathfinder
APPENDIX D

WEBSITE PAGES
Welcome to:  

Home of the Almeria-Mars Pathfinder!

Take the pathfinder for a spin around the colony. Just don’t forget to complete the "mission quiz".
Mission Control

**ROV ACCESS**
Operate the ROV to find ten information cards on the colony walls. Once you have read all ten cards, test your knowledge by taking the MISSION QUIZ.

**CONTROL TRAINING**
This tutorial made with Macromedia Authorware will teach you the controls. (2-10 min loading time)

**OVERHEAD CAMERA**
(useful when docking the ROV). It refreshes every 3 seconds.

**VIRTUAL MISSION**
You can click on thumbnails, displaying the necessary information to complete the MISSION QUIZ.

**Making Almeria Mars**

http://www.MarsROV.com

If you have questions or comments feel free to email me at MrWood@aplusteacher.net

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Mission Request Form

The Almeria-Mars Pathfinder is available for civilian use during weekdays, 8:00 a.m. - 3:00 p.m. The ROV is presently at its docking station. Please fill in the request form to activate it. Allow 24 hours for a response. A username and password will be emailed to you with your mission clearance.

Name: 
Email address: 
Date of requested mission: 
Time of requested mission: 
School Name: 

*required information

Submit | Reset
Click on the thumbnails to view the info cards, then take the Almeria-Mars Pathfinder Virtual Mission.

If you have questions or comments, feel free to email me at MrWood@aplateacher.net.
APPENDIX E

HYPERTEXT MARKUP LANGUAGE/JAVASCRIPT CODE TO
CALL REMOTELY OPERATED VEHICLE SUBROUTINES
AND POLL SENSOR DATA
HTML/JavaScript Code to Call ROV Subroutines and Poll Sensor Data

```
<html>
<head>
<title>MISSION OPS - T-18 INTERFACE</title>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1">
<script language="JavaScript">

var dummy = new Image();
var WebRCXURL = 'http://almeriams.fusd.net:7070/';
var Datalmage = new Image();
var Timeout=0;
var Sensor=0;
var Attempts = 20;

// Extra code used for display formatting only
var Degree = String.fromCharCode(186);
var Percent = String.fromCharCode(37);
var Colon = String.fromCharCode(58);
var Ratio = .2971014;

// This section gets sensor readings and formats them for output.
function SensorVal(x,y){
  // First digit is source 0..F, second digit is number 0,1,2
  // Source 9 is sensor reading, source 0 is variable
  // check the Spirit docs for full list
  SensorCode=x;
  OutputCode=y;
  GetReading(SensorCode,OutputCode);
}
function GetReading(SensorCode,OutputCode){
  delete Datalmage;
  Datalmage = new Image();
  Datalmage.src=WebRCXURL+'P'+SensorCode+Math.random();
  window.setTimeout('TryReading(OutputCode)',1000);
}
function TryReading(OutputCode){
  Timeout++;
  if (Timeout>Attempts){
    Timeout=0;
    OnFailure();
  }
  else if (Datalmage.complete){
    Sensor=GetNumber();
    Timeout=0;
    if (OutputCode=="1"){
      OnReading1();
    }
  }
```

60
if (OutputCode=="2"){
    OnReading2();
}
if (OutputCode=="3"){
    OnReading3();
}
else
    // msec per attempt is here
    window.setTimeout('TryReading()',100);

function GetNumber(){
    return ((Datalmage.width)*(Datalmage.height-2));
}
function OnReading1(){
    document.javacam.meterbox.value=parseInt(Sensor*Ratio)+Degree;
}
function OnReading2(){
    document.javacam.meterbox.value=Sensor+Percent;
}
function OnReading3(){
    hours = parseInt(Sensor/60);
    minutes = SensorparseInt(Sensor/60)*60;
    if (hours < 10){hours="0"+hours;}
    if (minutes < 10){minutes="0"+minutes;}
    document.javacam.meterbox.value=hours+Colon+minutes;
}
function OnFailure(){
    // You can increase the number of attempts if you like.
    alert("WebRCX not responding, or maybe the network is clogged.");
}

// -->
</SCRIPT>

<SCRIPT LANGUAGE="JavaScript">
<!-

var dummy = new Image();
var Delay = 1000;
var timerRunning = false;
var WebRCXURL = 'http://almeriams.fusd.net:7070/';

// This section sends commands to the RCX after a delay.
function Activate(x)
{
    prog=x;
    checkTimer();
}
setTimeout('Command(prog)', Delay);
timerRunning = true;
}
function checkTimer()
{
    if (timerRunning)
        alert('Slow Down!');
}
function Command(prog)
{
    timerRunning = false;
    dummy.src=WebRCXURL+prog+Math.random();
}

// -->
</SCRIPT>
</head>
<body bgcolor="#000000">
<table cellspacing="0" cellpadding="0" border="0" align="center" height="347">
<tr>
    <td width="5" height="5" valign="top"></td>
    <td width="158" height="5" valign="top"></td>
    <td width="45" height="5" valign="top"></td>
    <td width="259" height="5" valign="top"></td>
    <td width="246" height="5" valign="top"></td>
</tr>
<tr>
    <td width="5" height="62" valign="top"></td>
    <td width="203" height="181" colspan="2" rowspan="4" valign="bottom"><img src="back5.jpg" width="206" height="184"></td>
    <td width="259" height="62" valign="top"><img src="back2.jpg" width="259" height="62"></td>
APPENDIX F

NOT QUITE C SCRIPTS FOR RCX PROGRAMMABLE BRICK
NQC Scripts for RCX Programmable Brick

ROV Reverse Direction

task main()
{
  StopAllTasks();
}

task back1()
{
  OnRev(OUT_A+OUT_B);
  Wait(100);
  Off(OUT_A+OUT_B);
}

task back5()
{
  OnRev(OUT_A+OUT_B);
  Wait(350);
  Off(OUT_A+OUT_B);
}

task back10()
{
  OnRev(OUT_A+OUT_B);
  Wait(700);
  Off(OUT_A+OUT_B);
}

ROV Forward Direction

task main()
{
  StopAllTasks();
}

task forward1()
{
  OnFwd(OUT_A+OUT_B);
  Wait(100);
  Off(OUT_A+OUT_B);
}

task forward5()
{
  OnFwd(OUT_A+OUT_B);
  Wait(350);
Off(OUT_A+OUT_B);
}
task forward10()
{
    OnFwd(OUT_A+OUT_B);
    Wait(700);
    Off(OUT_A+OUT_B);
}

ROV Turn Right

task main()
{
    StopAllTasks();
}
task right22()
{
    OnFwd(OUT_A);
    OnRev(OUT_B);
    Wait(150);
    Off(OUT_A+OUT_B);
}
task right45()
{
    OnFwd(OUT_A);
    OnRev(OUT_B);
    Wait(300);
    Off(OUT_A+OUT_B);
}
task right90()
{
    OnFwd(OUT_A);
    OnRev(OUT_B);
    Wait(600);
    Off(OUT_A+OUT_B);
}

ROV Turn Left

task main()
{
    StopAllTasks();
}
task left22()
{ 
OnRev(OUT_A); 
OnFwd(OUT_B); 
Wait(150); 
Off(OUT_A+OUT_B); 
}

task left45()
{ 
   // Turn Left for required time span. 
   OnRev(OUT_A); 
   OnFwd(OUT_B); 
   Wait(300); 
   Off(OUT_A+OUT_B); 
}

task left90()
{ 
   OnRev(OUT_A); 
   OnFwd(OUT_B); 
   Wait(600); 
   Off(OUT_A+OUT_B); 
}

ROV Camera Control/ Operator Alert

task main()
{ 
   StopAllTasks(); 
}

task up()
{ 
   OnRev(OUT_C); 
   Wait(2); 
   Float(OUT_C); 
}

task down()
{ 
   OnFwd(OUT_C); 
   Wait(2); 
   Float(OUT_C); 
}

task alert()
{ 
   PlayTone(1000,50); Wait(50); 
   PlayTone(500,50); Wait(50); 
}
PlayTone(1000,50); Wait(50);
PlayTone(500,50); Wait(50);
PlayTone(1000,50); Wait(50);
PlayTone(500,50); Wait(50);
PlayTone(1000,50); Wait(50);
PlayTone(500,50); Wait(50);
PlayTone(1000,50); Wait(50);
PlayTone(500,50); Wait(50);
PlayTone(1000,50); Wait(50);
PlayTone(500,50); Wait(50);
}

MS-DOS Upload Batch File

cd\lego
nqc -firmware c:\lego\firm0309.lgo
nqc -d -pgm 2 left.nqc
nqc -d -pgm 4 backward.nqc
nqc -d -pgm 5 camera.nqc
nqc -d -pgm 1 forward.nqc
nqc -d -pgm 3 right.nqc
nqc -far
nqc -sleep 0
<table>
<thead>
<tr>
<th>Numb.</th>
<th>Color</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Light-Blue</td>
<td>3005.DAT Brick 1 x 1</td>
</tr>
<tr>
<td>4</td>
<td>Black</td>
<td>3065.DAT Brick 1 x 2 without Centre Studs</td>
</tr>
<tr>
<td>4</td>
<td>Light-Red</td>
<td>3007.DAT Brick 2 x 8</td>
</tr>
<tr>
<td>2</td>
<td>Black</td>
<td>5306.DAT Electric Brick 2 x 2 x 2/3 with Wire End</td>
</tr>
<tr>
<td>1</td>
<td>Light-Green</td>
<td>6035.DAT Electric Light &amp; Sound Brick 1 x 2 with Single Side Light</td>
</tr>
<tr>
<td>1</td>
<td>Cyan</td>
<td>2982C01.DAT Electric Light Sensor (Complete Assembly Shortcut)</td>
</tr>
<tr>
<td>1</td>
<td>Light-Red</td>
<td>884.DAT Electric Mindstorms RCX (Complete Assembly Shortcut)</td>
</tr>
<tr>
<td>1</td>
<td>Cyan</td>
<td>2977C01.DAT Electric Rotation Sensor (Complete Assembly Shortcut)</td>
</tr>
<tr>
<td>1</td>
<td>Light-Gray</td>
<td>2838C01.DAT Electric Technic Motor 9V</td>
</tr>
<tr>
<td>1</td>
<td>Yellow</td>
<td>879.DAT Electric Touch Sensor Brick 3 x 2 (Complete Assembly Shortcut)</td>
</tr>
<tr>
<td>3</td>
<td>Light-Gray</td>
<td>3710.DAT Plate 1 x 4</td>
</tr>
<tr>
<td>4</td>
<td>Light-Blue</td>
<td>3710.DAT Plate 1 x 4</td>
</tr>
<tr>
<td>1</td>
<td>Light-Blue</td>
<td>3020.DAT Plate 2 x 4</td>
</tr>
<tr>
<td>3</td>
<td>Light-Gray</td>
<td>3832.DAT Plate 2 x 10</td>
</tr>
<tr>
<td>1</td>
<td>Light-Gray</td>
<td>3033.DAT Plate 6 x 10</td>
</tr>
<tr>
<td>1</td>
<td>Black</td>
<td>32062.DAT Technic Axle 2 Notched</td>
</tr>
<tr>
<td>2</td>
<td>Black</td>
<td>3706.DAT Technic Axle 6</td>
</tr>
<tr>
<td>1</td>
<td>Magenta</td>
<td>3706.DAT Technic Axle 6</td>
</tr>
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<td>3707.DAT Technic Axle 8</td>
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<td>3708.DAT Technic Axle 12</td>
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<td>6538A.DAT Technic Axle Joiner</td>
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<td>3749.DAT Technic Axle Pin</td>
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<td>3700.DAT Technic Brick 1 x 2 with Hole</td>
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<td>3701.DAT Technic Brick 1 x 4 with Holes</td>
</tr>
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<td>3894.DAT Technic Brick 1 x 6 with Holes</td>
</tr>
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<td>Light-Blue</td>
<td>3895.DAT Technic Brick 1 x 12 with Holes</td>
</tr>
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<td>3703.DAT Technic Brick 1 x 16 with Holes</td>
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<td>32039.DAT Technic Connector with Axlehole</td>
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<td>3648.DAT Technic Gear 24 Tooth</td>
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<td>3650A.DAT Technic Gear 24 Tooth Crown</td>
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<td>6588.DAT Technic Gearbox 2 x 4 x 3 &amp; 1/3</td>
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<td>32009.DAT Technic Liftarm 1 x 11.5 Double Bent</td>
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<td>32002.DAT Technic Pin 3/4</td>
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<td>4459.DAT Technic Pin with Friction</td>
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<td>3738.DAT Technic Plate 2 x 8 with Holes</td>
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<td>4716.DAT Technic Worm Screw</td>
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<td>6595.DAT Wheel 49.6 x 28 VR</td>
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<td>71427.DAT Electric Technic Mini-Motor 9v</td>
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APPENDIX H

THREE DIMENSIONAL RENDERED IMAGES
Dear Mr. Wood:

Your application to use human subjects, titled, "Almeria-Mars: A Web Based Simulation" has been reviewed and approved by the Institutional Review Board (IRB). Your informed consent document is attached. This consent document has been stamped and signed by the IRB chairperson. All subsequent copies used must be this officially approved version. A change in your informed consent requires resubmission of your protocol as amended.

You are required to notify the IRB if any substantive changes are made in your research prospectus/protocol, if any unanticipated adverse events are experienced by subjects during your research, and when your project has ended. If your project lasts longer than one year, you (the investigator/researcher) are required to notify the IRB by email or correspondence of Notice of Project Ending or Request for Continuation at the end of each year. Failure to notify the IRB of the above may result in disciplinary action. You are required to keep copies of the informed consent forms and data for at least three years.

If you have any questions regarding the IRB decision, please contact Michael Gillespie, IRB Secretary. Mr. Gillespie can be reached by phone at (909) 880-5027, by fax at (909) 880-7028, or by email at mgillesp@csusb.edu. Please include your application identification number (above) in all correspondence.

Best of luck with your research.

Sincerely,

Joseph Lovett, Chair
Institutional Review Board

JL/mg

cc: Prof. Eun-Ok Baek, Department of Science, Math, & Technology
REFERENCES


