

ENVISIONING 3D LEARNING ENVIRONMENTS IN ENVIRONMENTAL
EDUCATION:
AN EXPLORATION OF THE KONZA PRAIRIE

by

NATALIE WEBB

A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF LANDSCAPE ARCHITECTURE

Department of Landscape Architecture and Regional & Community Planning
College of Architecture, Planning & Design

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Approved by:

Major Professor
Howard Hahn

ABSTRACT

“There is an alarming gap between awareness and action on [environmental issues]” (Sheppard, 2005). Public awareness of how to cope and change with these issues is lacking (Sheppard, 2004; Nicholson-Cole, 2005; Dockerty et al., 2005), but new visualization technologies can begin to bridge the gap through environmental education.

Environmental education focuses on the user exploring an environment, environmental issues, problem solving and ways to mitigate these issues. While the younger generations (middle to high school students) are much more aware of current and future environmental issues than older generations, the solutions to these problems may not be so apparent. By combining the need to educate young adults about climate change, regional ecosystem climate mitigation, and ecological management for technologically driven youth, middle and high school students can better understand their environment’s impact on climate-change regulation.

Through literature synthesis, documentation of existing visualization exhibits and technologies, and preliminary technology exploration, a production process, criteria, framework, and technology recommendations were established. These components informed the final storyboards, which visually organized a proposal to build a 3D learning environment focused on the Konza Prairie and its ecological management practices.



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An Exploration of the Konza Prairie

A report submitted in partial fulfillment of the requirements for the degree:
Master of Landscape Architecture
Department of Landscape Architecture and Regional & Community Planning
College of Architecture, Planning and Design
Kansas State University
Manhattan, Kansas

Committee:

Howard Hahn, Department of Landscape Architecture and Regional & Community Planning
Dr. Brent Chamberlain, Department of Landscape Architecture and Regional & Community Planning
Dr. Lauri Baker, Department of Communications and Agricultural Education

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THE COLLEGE of
ARCHITECTURE, PLANNING & DESIGN // K-STATE



ABSTRACT

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01

INTRODUCTION

KONZA PRAIRIE ECOLOGICAL MANAGEMENT: REACHING THE PUBLIC THROUGH ENVIRONMENTAL EDUCATION AND VISUALIZATION TECHNOLOGY

“There is an alarming gap between awareness and action on [environmental issues]” (Sheppard, 2005). Public awareness of how to cope and change with these issues is lacking (Sheppard, 2004; Nicholson-Cole, 2005; Dockerty et al., 2005), but new visualization technologies can begin to bridge the gap through environmental education.



Visualizations are being introduced to accelerate social learning, and affect substantial environmental policy. The need for technological and lifestyle changes surfaced from these applications (Sheppard, 2005). Geographic Information Systems (GIS) and remote sensing have been used to communicate environmental issues such as climate change with stakeholders, who then reported that the visualizations influenced their understanding and views on present and future policy changes and interventions (Cohen, 1997). Some of these effective visualizations include the effects of climate change on sea ice (University Corporation for Atmospheric Research, 2002) and similar visualizations of 'ozone holes' that were used in legislative arguments to ban fluorocarbons (Sheppard, 2005). The use of visualizations produced for environmental education about important environmental issues is still in the early stages.

THE INQUIRY

What is the value and production process of 3D learning environments in the Konza Prairie's environmental education, related to ecological management?

THE OUTCOME

The findings from the exploration and validation of 3D learning environments in environmental education provided a foundation for the use of 3D learning environments. This foundation then informed the production process, criteria and framework for designing such environments, and was

specifically tailored to the Konza Prairie's ecological management of the prairie in the Flint Hills. This production process and criteria were based in existing production processes and literature, and then used to create a production framework for the Konza Prairie 3D learning environment. This framework provided base information, storypoints for the information, spatial data for wayfinding checkpoints, and storyboarding ideas linked to each checkpoint. This framework provided exploratory information about how to conceptualize this 3D learning environment, according to the original designer's intent. A technology exploration of several programs, data compatibilities and display technologies informed the framework for a 3D learning environment.

The final product includes relevant information about the ecological management of the Konza Prairie and its long-term ecological research (LTER) program, educating middle and high school students about ecological management and climate-change mitigation, including supplemental facts about the Konza Prairie. This information is expressed in conceptual storyboarding and evaluation content.

FIGURE 1.1: (right) Konza Prairie Grasses in Spring
Source: Photo by Natalie Webb





02 **BACKGROUND**



ENVIRONMENTAL EDUCATION IN ECOSYSTEM MANAGEMENT

Ecosystem management is an approach to natural resource management that aims to sustain ecosystems to meet both the ecological and human needs of the future (GreenFacts, 2014). Ecosystems have the ability to stabilize climate through natural carbon sequestration processes in a cost effective way and continued ecosystem service delivery. Regional ecosystems, like the Konza Prairie, are key climate regulators that absorb about half the CO₂ emissions from anthropocentric activities. The other half of CO₂ emissions is added to the atmospheric pool. The ecosystem absorption capacity of these emissions is declining by about 1% every decade and likely to decline at a faster rate due to global warming and increased anthropocentric activities. Therefore, there is an imbalance between emissions and the absorption capacity of these ecosystems. Ecosystem management can aid climate stabilization, and produces benefits in four main areas: social, economic, climate regulation and environmental. Social benefits include health, cultural and aesthetic values, community support, and securing livelihoods, particularly for the poor. Economic and environmental benefits both rely on resilient, healthy ecosystems to have the capacity to support service provisioning for either economic activity or long-term sustainability. Climate regulation benefits include the ecosystem's function as tools for mitigation through appropriate management to reduce natural sources of emissions, and an increased absorption capacity (Climate Change Report, 2013).

An ecosystems approach is the strategy for integrating land, water and living resource management to promote conservation and sustainable use in an equitable way, and is a holistic path to ecosystem management (Munang et al., 2014). While many researchers and scientists understand the usefulness of ecosystem management in climate stabilization, the public awareness of management practices and benefits still lags behind (Sheppard, 2005). 3D learning environments have the ability to increase the awareness and educate the public about the ecosystems they live in, the management practices that take place to maintain those ecosystems and the climate regulation benefits their environments can provide.

ENVIRONMENTAL EDUCATION, LEARNING AND VISUALIZATION

Environmental education is an educational process that allows individuals to explore environmental issues, engage in problem solving, and take action to improve the environment. As a result, individuals develop a deeper understanding of environmental issues and have the skills to make informed and responsible decisions about their lifestyle habits and environmental policy (Environmental Protection Agency, 2014). This process is similar to the constructivist learning theory in which people construct their own understanding and knowledge through personal experiences, and reflecting upon those experiences (Concept to Classroom, 2004). Visualizations can be teaching tools that align with constructivist fundamentals. Active exploration and manipulation of ideas in the visualization allow

users to create and understand new knowledge through their experiences (Dalgamo et al., 2002).

Visualizations are effective educational mediums that are successful in improving cognitive learning (related to knowledge and understanding of information), especially in visual learners (Sheppard, 2005). It is estimated that 60% of American students are visual-dominant learners, which means they process information best through visual learning in which movement, color, graphics and sound are involved in the learning process. Visual learning mirrors how the human mind naturally processes information, encourages spontaneous and natural learning through in-depth exploration of ideas and concepts (Rogers, 2000). In environmental education, learning through visualizations can affect how people view their environmental attributes, explore new environmental policies and help make informed and responsible decisions about environmental issues (Pettit et al., 2006).

Visualization is a visual communication tool that gives contextual information for content in the form of graphics (Marcum, 2002; Rodil et al., 2012). The visualizations are often a visual translation of complicated ideas or information, and an organization of data that allow the user to manage information complexity in a simple way (Marcum, 2002). Visualizations may offer advantages in rapidly advancing peoples' knowledge and understanding of complex environmental problems through the simplification and organization of information, and can be used to communicate scientific information, models of environmental planning methods and other environmental issues (Pettit

et al., 2011; Sheppard, 2005). By developing a deeper understanding of environmental issues through problem solving and exploration, a visualization can offer insight into future environmental scenarios by making the future seem more "real," potentially affecting decisions related to environmental issues (Sheppard et al., 2011; Sheppard 2005; Sheppard, 2002).

DEFINING 3D LEARNING ENVIRONMENTS AS VISUALIZATION TOOLS

There are three broad categories of graphics in environmental visualizations: 1) image draping: composite still images created by a single image or multiple images draped over, or positioned on a 3D terrain, 2) photorealistic rendering: a still image, or an animation from a series of still images that has vegetation or landscape incorporated for a more realistic representation of a space, and 3) virtual environments which allow a user to explore an interactive environment freely, sometimes hyperlinked with information pertaining to the world (Appleton et al., 2002). A virtual environment can also be defined as a virtual space to enable interaction with display data. To further define the visualization type that will be produced as a result of this project, “3D learning environment” will replace “virtual environment.” According to Wann and Mon-Williams (1996), a 3D environment “capitalizes upon natural aspects of human perception by extending visual information in three spatial dimensions and may supplement this information with other stimuli and temporal changes.” Three dimensionality, smooth temporal changes and interactivity are the most important features that distinguish 3D learning environments from other types of virtual learning environments. In addition, increased immersion, graphic fidelity and a higher level of active learner participation are important contributors to 3D learning environments (Dalgamo et al., 2002).

KONZA PRAIRIE ECOLOGICAL MANAGEMENT PRACTICES: CONTENT FOR A 3D LEARNING ENVIRONMENT

The Flint Hills is a 1.6 million hectare region in eastern Kansas and northeast Oklahoma, characterized by a mesic grassland ecosystem and steep slopes with limestone soils. Jointly owned by Kansas State University and The Nature Conservancy, the Konza Prairie Biological Station (KPBS) is 3,487 hectares (8,617 acres) of native tallgrass prairie located within the Flint Hills Region, approximately 10 miles south of Manhattan, Kansas. Due to chert in the thin soils, the Konza Prairie is part of the largest unplowed tallgrass prairie in North America, and serves as a research site for mesic grasslands worldwide. Operated currently as a field research station by the Kansas State University Division of Biology, it is one of six long-term ecological research (LTER) sites. The station is “dedicated to a three-fold mission of long-term ecological research, education and prairie conservation.” The KPBS offers an outdoor research lab open to scientists and students to study the tallgrass prairie ecosystem (KPBS, 2014).

The KPBS focuses the LTER program on ecological management methods: fire, grazing and climate variability. Fire and grazing are ecological management practices that have taken place at the KPBS since 1972, to understand the effects that both have on the grassland ecosystem dynamics at multiple scales. The research includes studies across multiple ecological levels, spatial and temporal scales, and addresses the major abiotic drivers (climate and fire) and biotic interactions (herbivory, competition, mutualism and



FIGURE 2.1: Flint Hills Region Location Map

Source: Adapted from Google Maps

predation) that shape the grassland ecosystems (Konza Prairie Long Term Ecological Research, 2014).

Fire is essential to mesic grassland ecosystems. Human alteration of fire frequency is a key element of global change in these grasslands. Once a naturally occurring phenomenon, fire is now managed by people to manipulate the fire frequency. Fire on the Konza Prairie regulates the presence of woody plant species, maintaining the grassland character. Replicated watersheds on the Konza Prairie are burned annually, or in 2-, 4-, or 20-year frequencies, usually at the end of the dormant season when fires naturally occur from

lightning or when other regional burns are happening (Core LTER Research, 2014).

Another critical research driver of grasslands is climate, since changes in climate affect most ecosystems. Land use and land cover change on the Konza Prairie is a primary focus of the long-term ecological research, which includes: the impacts of fire-grazing regimes, causes and consequences of woody-plant expansion, and ecosystem restoration. Within this category, the LTER is focused on the ecological responses to climatic variability and climate change, responses to altered biogeochemical cycles in terrestrial grassland ecosystems, aquatic ecology and



FIGURE 2.2: Konza Prairie Aerial Location Map

Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014

<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

effects of water quality and hydrology, and regionalization, remote sensing and modeling (Core LTER Research, 2014).

The Konza Prairie's LTER research drivers are used as catalysts for the 3D learning environment content. Fire, grazing and climatic variability are key components to educate the user about the Konza Prairie's ecosystems approach to climate-change mitigation. In addition to specific ecosystem management methods, the Konza Prairie's history, vegetation, nature trails, hydrology and landscape character is included in the 3D learning environment.

PROJECT LOCATION: KONZA PRAIRIE

The Konza Prairie Biological Station was chosen for its close proximity and on-going research connections to Kansas State University, and potential to involve community stakeholders in the final 3D learning environment's use. These potential stakeholders include the Konza Prairie Biological Station researchers, Kansas State University, Flint Hills Discovery Center and local school districts.



METHODS

The Konza Prairie Biological Station is a field research station operated by K-State's Division of Biology, and a site-based long-term ecological research (LTER) station funded by the National Science Foundation (1980). The LTER program focuses on fire, grazing and climatic variability, drivers of ecological processes, and patterns consistent with mesic grasslands worldwide. The Konza Prairie also serves as a regional climate mitigator, absorbing about half of the CO₂ emissions from anthropocentric activities. Development of the 3D learning environment is outlined in the four phase framework represented in Figure 3.1. Each phase will be described in more detail in the following sub-sections.



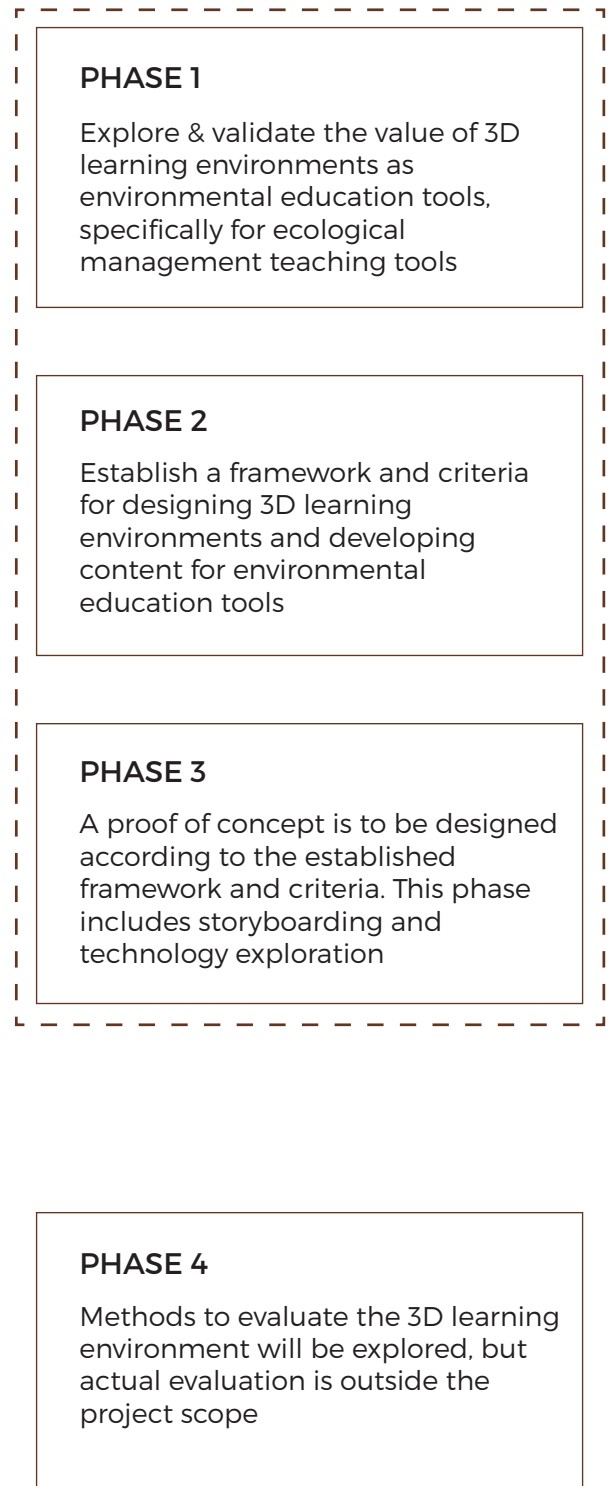
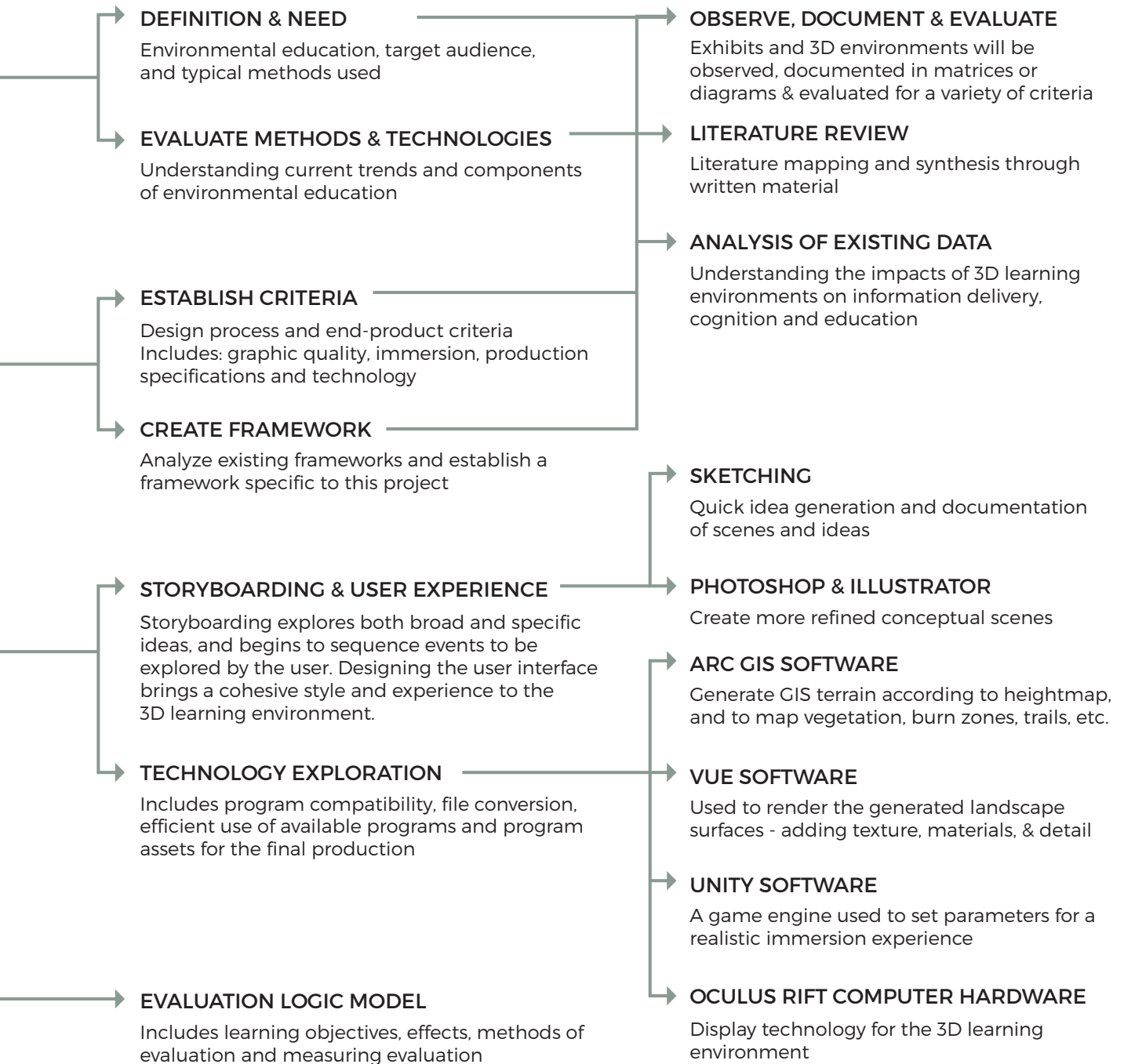


FIGURE 3.1: Methodology Workflow

Source: Created by Natalie Webb



PHASE 1: EXPLORE AND VALIDATE THE VALUE OF 3D LEARNING ENVIRONMENTS AS ENVIRONMENTAL EDUCATION TOOLS

Establishing the need for environmental education within a target audience provided a foundation for subsequent project methods. Environmental education shares many similar attributes with “standard” education and learning theories, but the focus may be different. Literature review of current environmental issues (both global and local), learning theories and strategies, and results and repercussions of environmental education have been synthesized, and applied to the Konza Prairie’s environmental education agenda.

Evaluating the current methods and technology used in environmental education provided an initial understanding of current technology trends, and components of environmental education. Observation and documentation of current exhibits at the Flint Hills Discovery Center in Manhattan, KS, a venue dedicated to educating the public about the Flint Hills, provided insight into a variety of technologies and methods to deliver environmental-education information.

PHASE 2: PRODUCTION PROCESS, CRITERIA AND FRAMEWORK FOR DESIGNING 3D LEARNING ENVIRONMENTS

The visualization production process provided guidance and clarity for the prototype design process. Analyzing animation production processes from industry-leading animation companies and visualization processes found in literature provided precedents to create a tailored process.

In addition to the production process, specific criteria was established through literature synthesis to design the 3D learning environment. This criteria provided standards for graphic quality, level or type of immersion, production specifications, interactivity and technology types that were acceptable for the prototype visualization. Interaction and immersion strategies were a major component of the 3D learning environment, and were researched through literature synthesis and documentation of the Flint Hills Discovery Center exhibit inventory. Recommendations include computer requirements and component types to be used in the visualization design.

A framework for designing 3D learning environments was produced with the production process and criteria in mind. This framework could be replicated for other projects, but serves as an informational checklist to design the final visualization.

PHASE 3: STORYBOARDING AND TECHNOLOGY EXPLORATION

Generating content for the 3D learning environment required information collection about the Konza Prairie from landscape characteristics, to historical context, to ecological management tools. This information was readily available in digital and print formats, and was then organized by categories for content development. Spatial information was also collected through the Konza Prairie Biological Station’s spatial data website, organized in ArcGIS, and used to produce base map information for the framework categories.

Storyboarding was used to brainstorm content and visualize displays to be used in the 3D learning environment. Initial storyboarding provided general scene layouts, content and additional notes about interactivity and information display. These became the motivation for brainstorming final storyboarding ideas, which would be either sketched or digitally produced. Written storyboarding and idea generation were added to the visualization framework sheets for information clarity, ease of access, and identification of potential learning “checkpoints” in the 3D learning environment. Once all framework sheets included basemap information, general environmental education points, specific storyboarding checkpoint information and the location of these checkpoints, a final storyboard was compiled. This storyboard served as the guide to designing a 3D learning environment for the Konza Prairie’s public ecological management and environmental education tool.

During the storyboarding phase, preliminary technology explorations were conducted. Component compatibility between established software programs were tested. Components were moved between programs as different filetypes and sizes, and documented for future reference.

The proof of concept, or designed 3D learning environment for the environmental education purposes of the Konza Prairie’s ecological management, followed the established production process, criteria, framework and final storyboards.

PHASE 4: EVALUATION

A logic model was proposed as an evaluation strategy for the 3D learning environment. This logic model included evaluation plans, such as pre- and post- testing and environmental attitudes testing within the game environment.

Because of time and budget limitations, a working prototype was only conceptualized, and not actually developed. Once developed and implemented as a pilot test, the education benefits of a 3D learning environment can be evaluated and reported.



ENVIRONMENTAL EDUCATION

ENVIRONMENTAL EDUCATION AND YOUNG ADULTS

One of many generations to recognize that climate change mitigation is an important factor of their future, middle and high school students (ages 11-18) are a generation of young adults who will be affected by climate change. UNICEF UK Climate Change Report (2013) reports that 75% of 11-16 year olds are worried about how climate change will affect their future, access to fresh food, clean water, adequate shelter and their education.



Although this is a report of children in the UK, conditions are similar in the United States. “Despite the skepticism of some adults, the awareness among children of both the tenderness of our planet and the threats to it from climate change is undiminished,” (UNICEF UK, 2013). By combining the need to educate young adults about climate change, regional ecosystem climate mitigation, and ecological management for technologically driven generations, middle and high school students can better understand their environment’s impact on climate change.

THE NEED FOR ENVIRONMENTAL EDUCATION

Environmental education is directed at understanding environmental issues and seeking solutions or mitigations to these issues. While the target audience’s generation is much more aware of current and future environmental issues than previous generations, solutions to these problems may not be so apparent. Specific to the Konza Prairie, most visitors may not understand why areas of the prairie are burned every spring. The Flint Hills prairie is also a complex ecosystem of interrelated geology, soils, hydrology, flora, and fauna. Environmental education can be used to explain to visitors or Flint Hills residents why certain ecosystem management techniques are being used and the benefits of doing so. By exposing young adults to these methods and techniques, this generation will have a better understanding of climate mitigation.

THE VALUE OF 3D LEARNING ENVIRONMENTS IN ENVIRONMENTAL EDUCATION

3D learning environments provide significant contributions to learning, such as: facilitating virtual access to inaccessible environments; facilitating task mastery through virtualized practice of dangerous or expensive tasks; improving learning through a realistic context; improving motivation through immersion; reducing the cognitive load through the integration of multisensory pathways; facilitating the exploration and understanding of complex knowledge bases, environments and systems; and facilitating the understanding of complex ideas through metaphorical representations (Dalgamo et al., 2002). Several of these contributions can be applied to the Konza Prairie 3D learning environment. For some potential visitors, the Konza Prairie is an inaccessible environment due to geographic location or terrain, inhospitable weather, user physical ability, or lack of available time to explore the prairie. Within the environment, users have the ability to virtually explore the Konza Prairie regardless of those constraints. The immersive nature of the environment provides focus and “interaction.”

CURRENT TECHNOLOGY & METHODS OBSERVATION

Observation and documentation of exhibits at the Flint Hills Discovery Center in Manhattan, KS, offered a sample of educational exhibits (see Figure 4.1). These exhibits ranged from text posters to an immersive theater experience. Information was gathered during two visits to the Flint Hills Discovery Center and organized

into a matrix, taking note of several key components to compare. These components included:

- Type of exhibit
- Approximate display size
- Immersion (yes/no)
- Degree of immersion (1-none, 5-total)
- Visuals (yes/no)
- Video (yes/no)
- Print media (yes/no)
- Digital media (not video; yes/no)
- Language audio (yes/no)
- Background audio (yes/no)
- Interactive touch (yes/no)
- 2D/3D/4D experience
- Portability (yes/no)
- Target audience size (small, medium, large)
- Pros and cons

This inventory only provided a general understanding of technologies available at one venue, and is not a full account of all technologies available for environmental education purposes.

DISPLAY	LARGE THEATER	CEILING DOME VIDEO	INTERACTIVE SCREENS
SIZE (APPROX.)	10' X 30'	40' DIAMETER	TYPICALLY 12" X 18"
IMMERSION (Y/N)	YES	NO	NO
DEGREE OF IMMERSION (1-NONE TO 5-TOTAL)	4	1	1
VISUALS (Y/N)	YES	YES	YES
VIDEO (Y/N)	YES	YES	YES
PRINT MEDIA (Y/N)	NO	NO	YES
LANGUAGE AUDIO (Y/N)	YES	NO	YES
BACKGROUND AUDIO (Y/N)	YES	YES	YES
INTERACTIVE TOUCH (Y/N)	NO	NO	YES
2D, 3D, 4D EXPERIENCE	4D	2D	2D, 3D
PORTABILITY (Y/N)	NO	NO	YES
AUDIENCE SIZE (S, M, L)	S, M, L	S, M, L	S, M

FIGURE 4.1: Flint Hills Discovery Center Exhibit Inventory

Source: Created by Natalie Webb

SMALL THEATER	GRAPHIC WALLS & DISPLAYS	BROCHURE OR PAMPHLET
8' X 12'	VARIES	8.5" X 11"
YES	NO	NO
3	1	1
YES	YES	YES
YES	NO	NO
YES	YES	YES
YES	NO	NO
YES	YES	NO
YES	YES	NO
2D, 3D	2D	2D
NO	YES	YES
S, M	S, M	S, M, L

REFLECTING ON THE EXHIBIT TYPES AT THE FLINT HILLS DISCOVERY CENTER

The Konza Prairie 3D learning environment differs from exhibits currently at the Flint Hills Discovery Center in three key areas: portability, size and information delivery. Each of the inventoried displays is stationary and compromises portability for display size. Displays such as the large theater, ceiling dome video, and small theater are bound to a physically large, immovable screen, but offer a sense of interactivity and immersion within the exhibit. Displays like the graphic walls and displays, interactive screens, brochures and pamphlets are more portable than the theater screen displays, but lack other exhibit aspects, like interactivity and immersion qualities. The Konza Prairie 3D learning environment provides display portability using the Oculus Rift, without compromising immersive interactivity. Although physically small, the portable display

technology provides a large, virtual display for the user to explore.

Information delivery varies in the different exhibit types, including video, print media, narrated text, interactive exploration and immersive topic focus. A consistent roadblock in information delivery was the lack of a multi-lingual exhibit. This aspect made most exhibits unproductive in information delivery, but some still included visuals that were universally understood. Audio in these exhibits sometimes confused the user, and did not complement the exhibit visuals. The Konza Prairie 3D learning environment provides a multi-lingual option to cater to a variety of audiences, both spoken, written and interactive information for cognitive reinforcement of ideas.



FIGURE 4.2: Flint Hills Discovery Center, Manhattan, KS
Source: Image by Natalie Webb

ABOUT THE FLINT HILLS DISCOVERY CENTER

“We aim to serve as a principal place for learning and understanding about the tallgrass prairie and the Flint Hills ecoregion in particular; to assure its long-term preservation” (The Vision, Flint Hills Discovery Center).

The Flint Hills Discovery Center serves as a regional environmental education venue with engaging exhibits for a variety of audiences. These exhibits focus on the Flint Hills, encouraging audiences to celebrate, explore and care about the tallgrass prairie ecosystem.

The Flint Hills Discovery Center provides a variety of youth and adult education programs, such as Preschoolers in the Flint Hills (ages 3-5), Adventure Camp (grades K-6), homeschooling programs, Girl Scout workshops, and programs for all ages such as on-site exhibit programs, Go See It! lectures and adult workshops.

With such a comprehensive list of educational programs for all ages and direct link to the mission, the Flint Hills Discovery Center is an ideal venue for the Konza Prairie 3D learning environment.



05 **CONCEPTS & UNDERSTANDING**



ANALYZING AND ESTABLISHING THE PRODUCTION PROCESS

The visualization production process for 3D learning environments is similar to animation production used at both DreamWorks Animation (see Figure 5.1) and Pixar Animation Studios (see Figure 5.2). These processes are categorized into three main steps: concept development, character development and scene refinement, and final touches and sound integration.

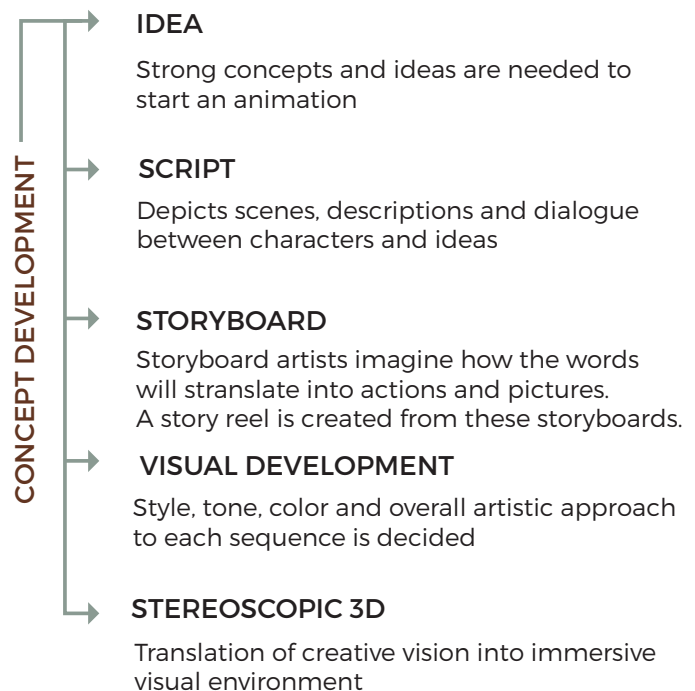
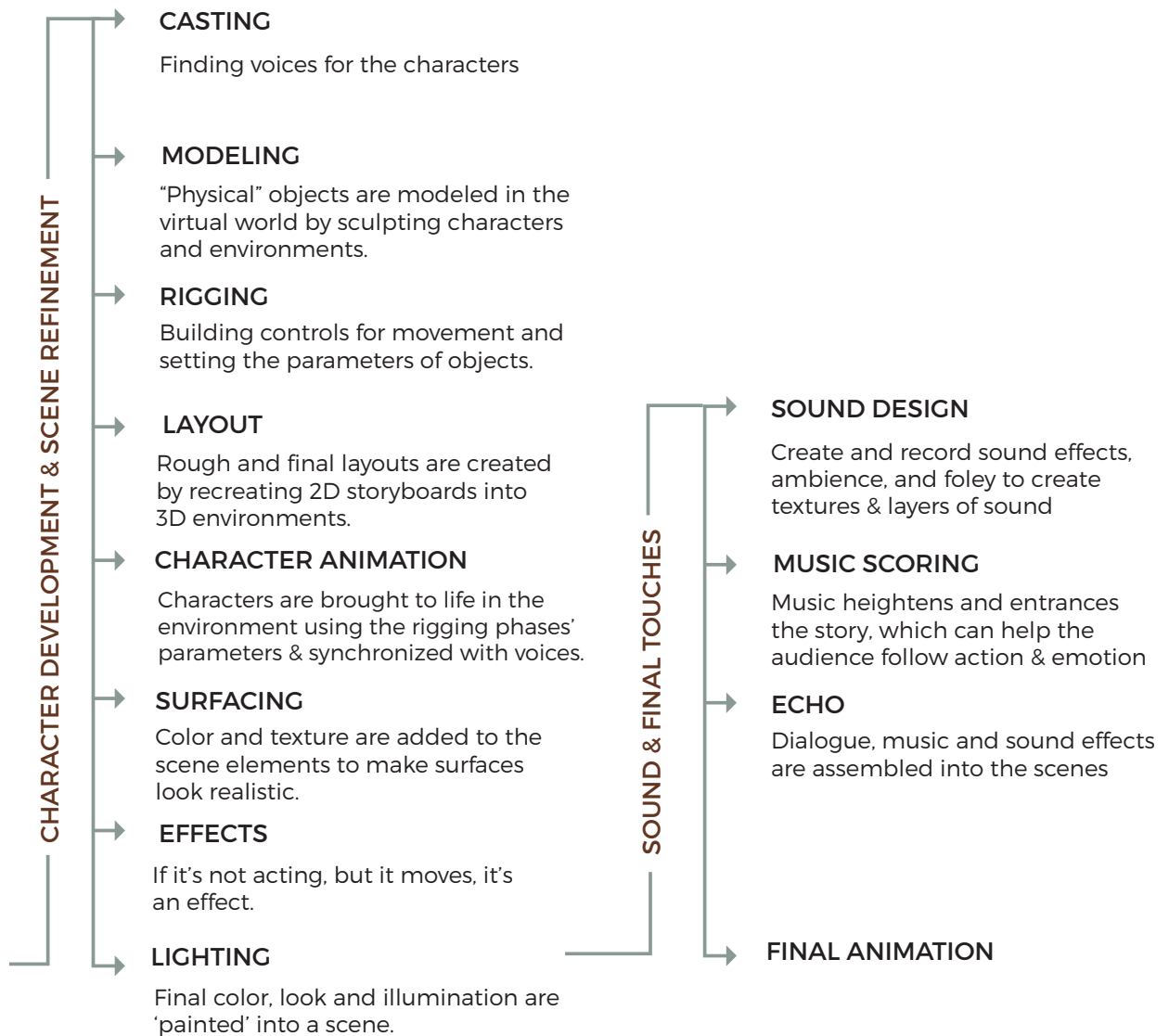


FIGURE 5.1: DreamWorks Animation Production Process
Source: Adapted from DREAMWORKS ANIMATION
<http://www.dreamworksanimation.com>



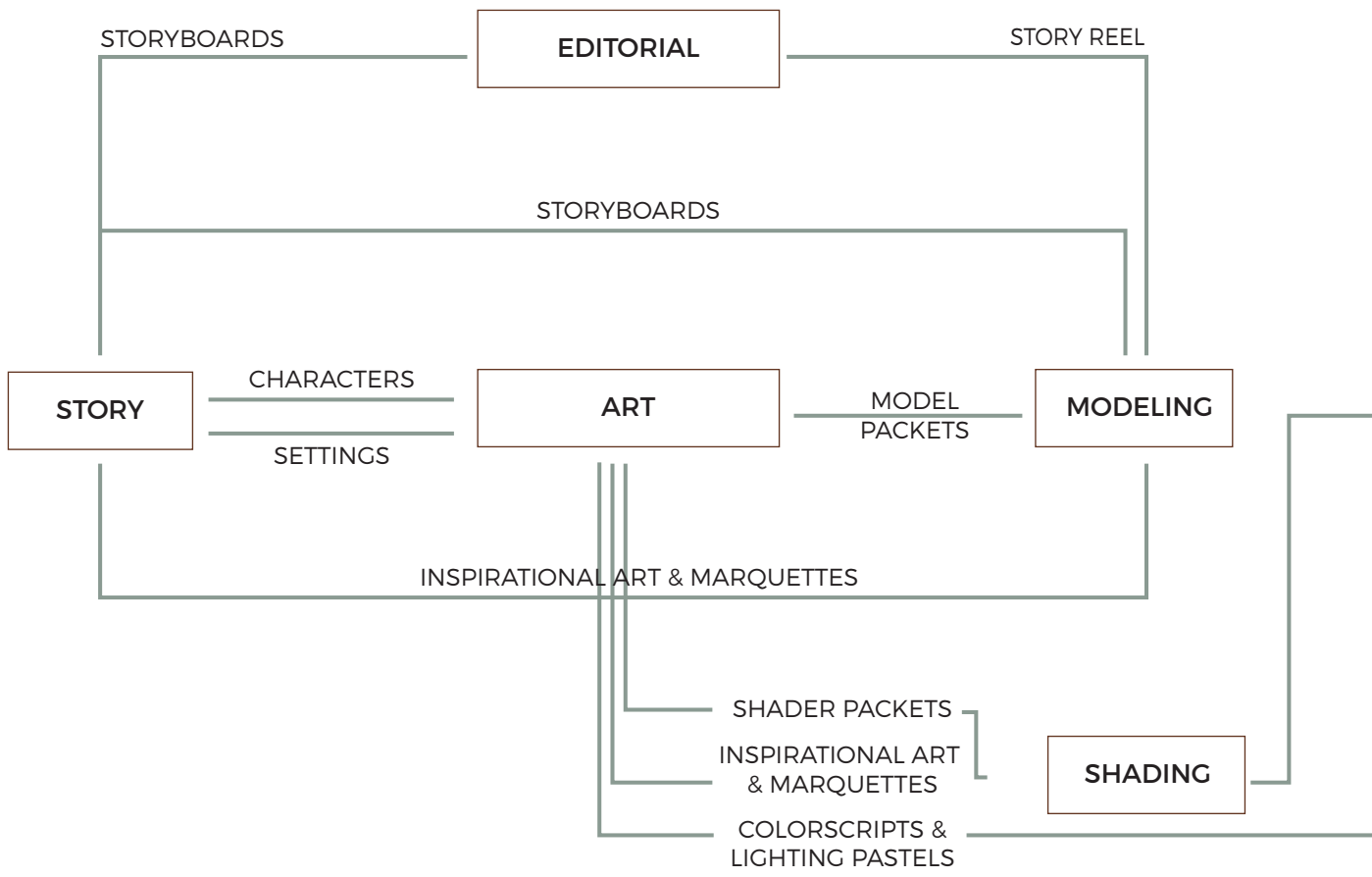
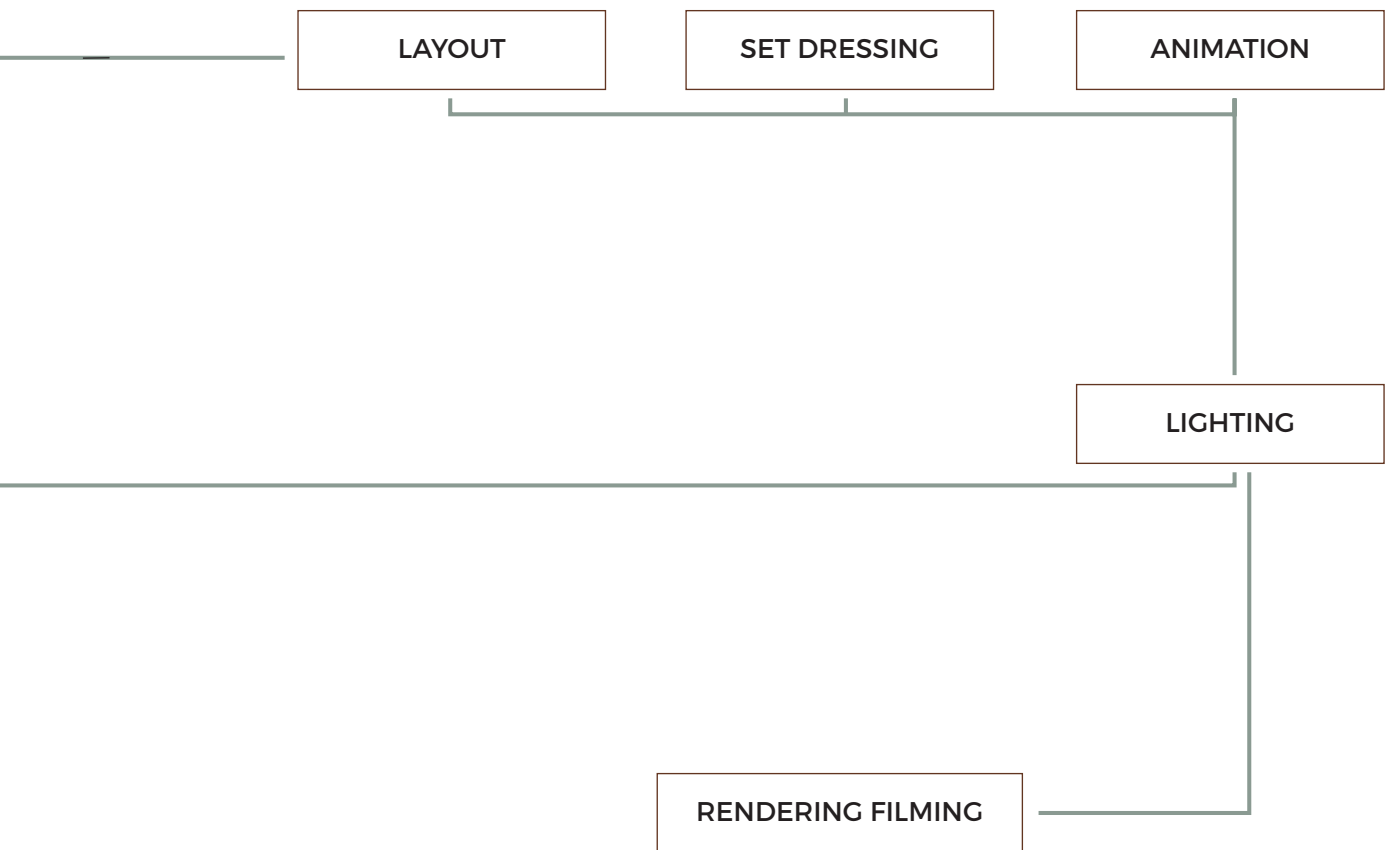


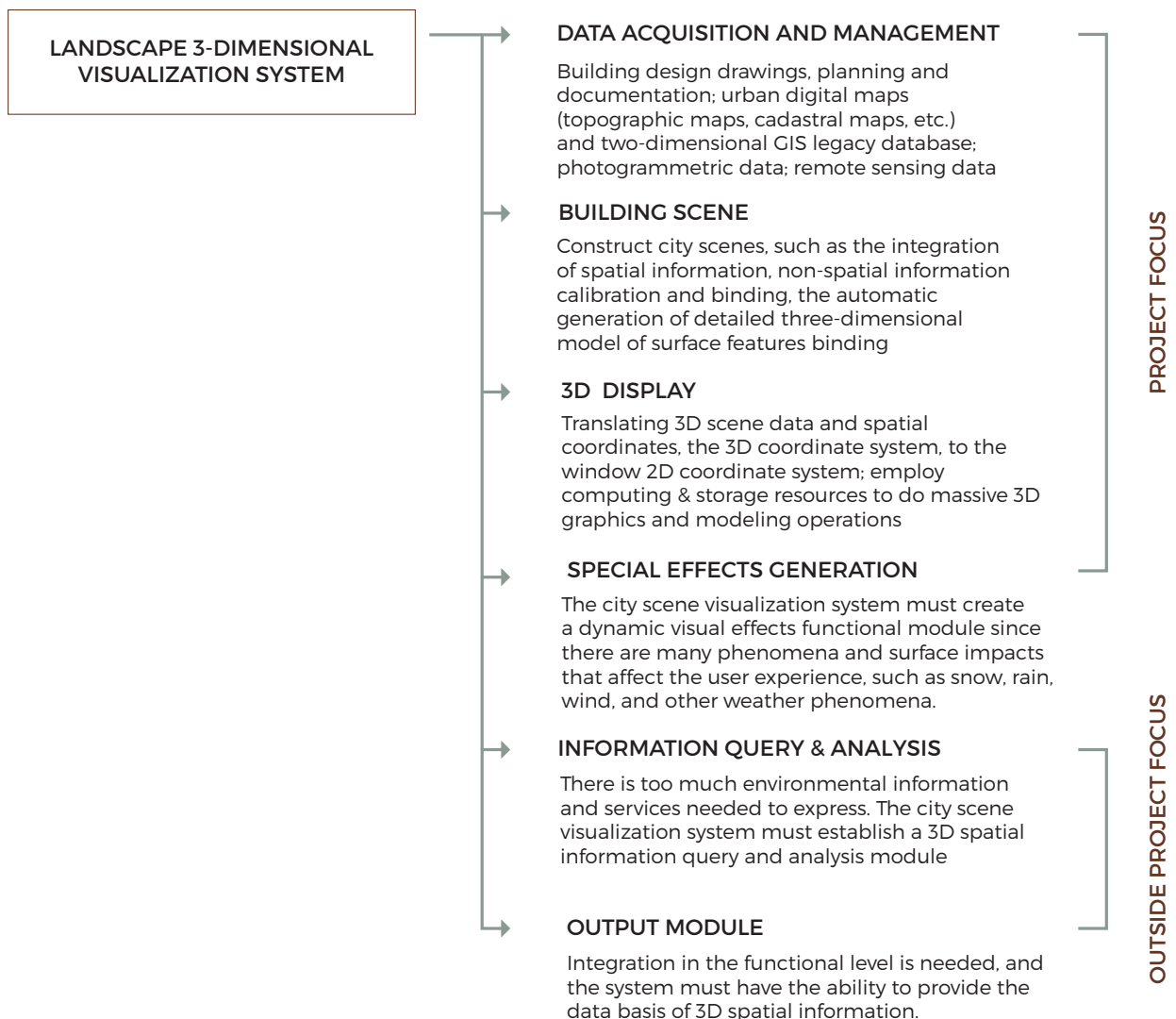
FIGURE 5.2: Pixar Animation Studios Production Process

Source: Adapted from "Designing a Pixar Film"
<http://www-inst.eecs.berkeley.edu/~cs194-8/Fa10Sp11/readings/F02.01/DesigningAPixarFilm.pdf>



Another production process proposed by Tan et al., 2011, is specific to urban visualization systems (see Figure 5.3) but the same process could be applied to the Konza Prairie 3D learning environment. This process differs from the animation production processes explored by DreamWorks Animation and

Pixar Animation Studios since the focus is for academic purposes, rather than entertainment. Information display takes priority over graphic accuracy, so less emphasis is put on the scene refinement.



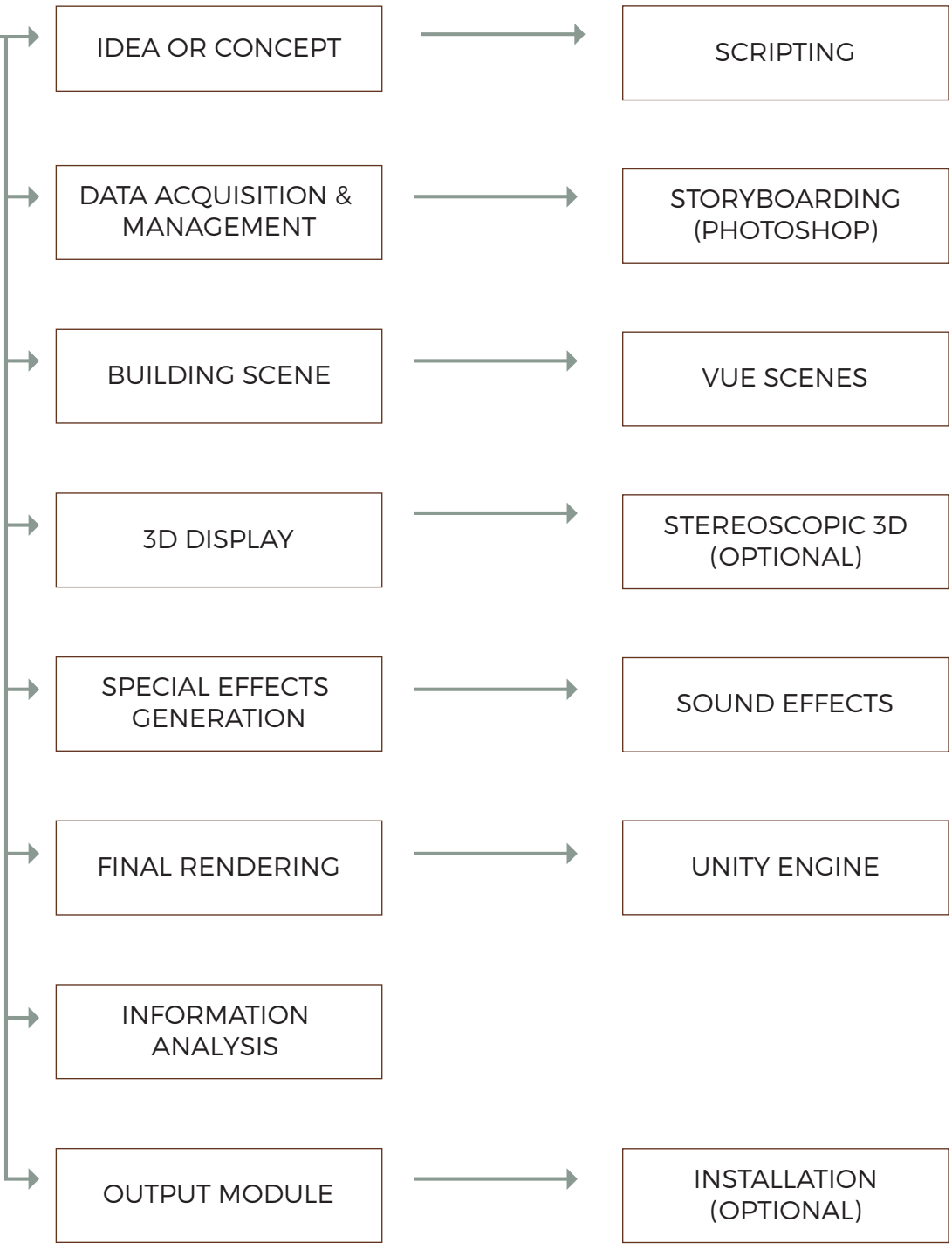
A PRODUCTION PROCESS FOR THE KONZA PRAIRIE 3D LEARNING ENVIRONMENT

A production process for creating 3D learning environments has been derived from the DreamWorks Animation, Pixar Animation Studios and Landscape 3D Visualization System models. This process combines and tailors each precedent process to specifically apply to the Konza Prairie 3D learning environment. The process is divided into 8 categories, with two categories currently outside the project scope. These categories are: 1) idea or concept, 2) data acquisition and management, 3) building scenes, 4) three-dimensional display, 5) special effects generation, 6) final renderings, 7) information analysis (outside project scope), and 8) output module (outside project scope). Each category is then broken down further into more detailed steps that contribute to the main category. This production process sets the foundation for the creation of the Konza Prairie 3D learning environment, and was followed for a streamlined production process.

FIGURE 5.3: (left) Basic Structure of Urban Scene Three-dimensional Visualization System

Source: Adapted from Design and Key Technology of Urban Landscape 3D Visualization System, Tan et al., 2011 <http://www.sciencedirect.com/science/article/pii/S1878029611003938>

PRODUCTION PROCESS FOR THE KONZA PRAIRIE
3D LEARNING ENVIRONMENT



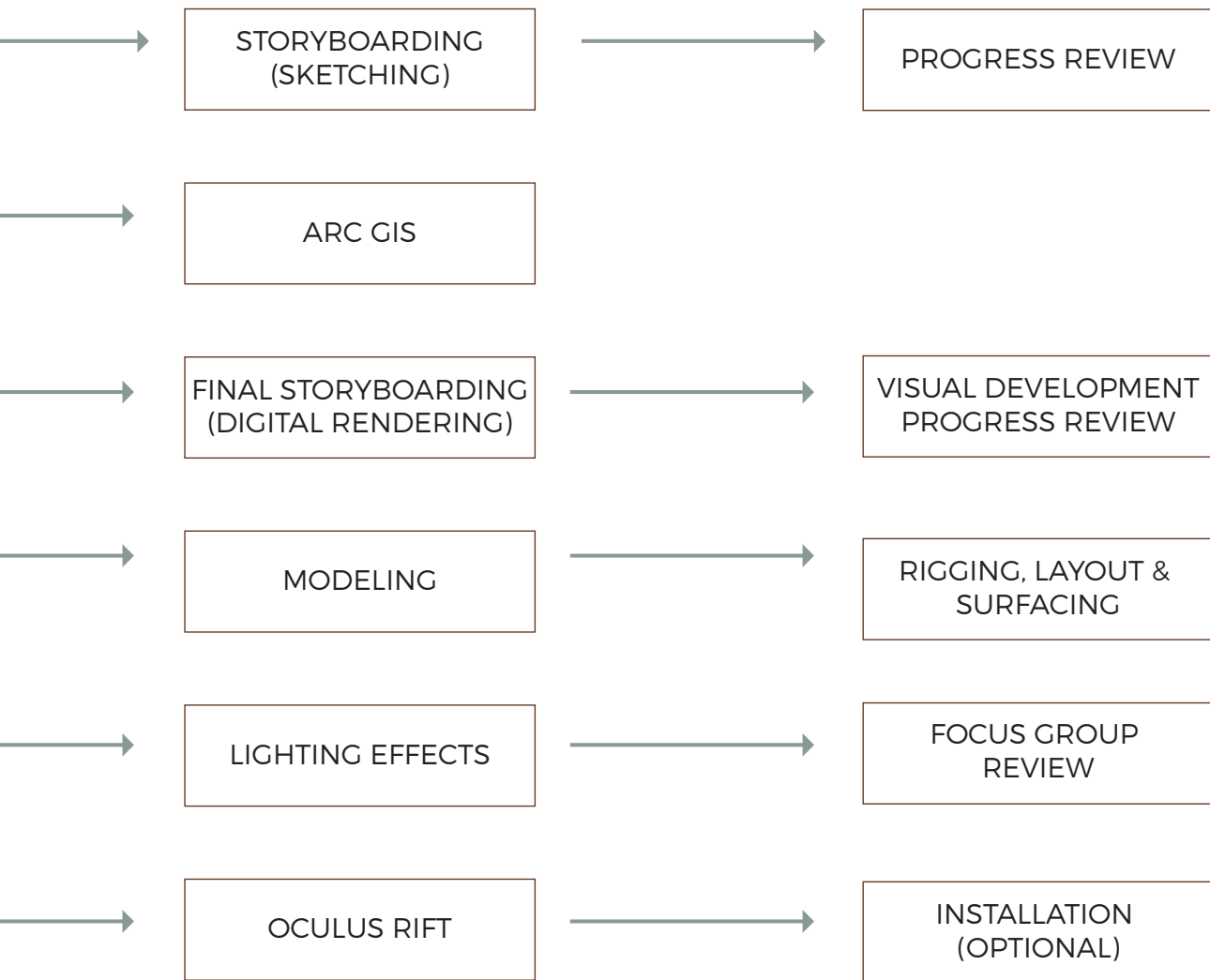


FIGURE 5.4: Konza Prairie 3D Learning Environment Production Process

Source: Created by Natalie Webb

CRITERIA BACKGROUND: DISPLAY TECHNOLOGY, IMMERSION & INTERACTIVITY

Display technology considers the qualities of the eye and human perception to determine the best possible visual presentation for specific content (Marcum, 2002), and can affect the graphic quality, immersion and interactivity.

The Flint Hills Discovery Center exhibit documentation included display technology information. The display-type ranged from printed information to an immersion theater, showing a variety of display technologies in one venue. This exhibit documentation is not a comprehensive list of all display technologies, but does offer insight into a broad range of display technology. Display size was also accounted for in the exhibit documentation, since size directly relates to spatial understanding. Physically large displays increase the performance of spatial tasks, mental map formation, memory of a space and sense of presence in a 3D environment (Bystrom et al., 1999).

Immersion is the extent to which [digital] displays are capable of delivering an illusion of reality to the senses of the user (Tan et al., 2006). The degree of immersion is dependent on how many senses are being stimulated by a 3D environment, with a certain level of consistency across all senses (Whitton, 2003). Users are most effective in a 3D environment when they feel their bodies are physically part of the visualization (Tan et al., 2006). Immersion has been identified as a factor to induce a behavioral response to visualization content, reducing a learner's cognitive load while improving task motivation, and is a key attribute that differentiates virtual

environments from 3D environments (Dalgamo et al., 2002).

Rapid technological development in display technologies, such as head mounted displays allow users to experience an immersive environment at multiple spatial scales with realistic 3D objects and shading, interaction with the environment through free movement and real-time feedback (Wang et al., 2006, Tarr and Warren, 2002). Head mounted displays and virtual reality goggles, such as the Oculus Rift, were not available for the Flint Hills Discovery Center inventory, but were taken into consideration for the final 3D learning environment display technology. The virtual reality headset offers an individual experience and exploration of 3D environments, and has several components that make the visual experience unique from other display technologies, including low latency head tracking, stereoscopic 3D, and wide field of view. The low latency 360-degree head tracking provides a seamless view of an environment, similar to a real-world environment.

Stereoscopic 3D is also a component of both DreamWorks Animation and Pixar Animation Studios' animation production process. This is a process of producing a feeling of depth in a film or animation that works similarly to the human eye. Finally, the Rift offers a wide field of view (approximately 100 degrees) that is beyond the human peripheral vision, creating opportunity for a fully immersive environment (Rift, 2014).

Interactivity, or learner control, is a component of 3D environments that encourages non-linear thinking and constructivist learning through discovery and free movement (Rogers, 2000). Interactivity

offers the ability to change the view position or direction of an environment, and manipulate, pick up or examine objects within that environment. With the movement of objects that simulate real-world movements, the user can have total control over the parameters or speed of the visualization (Dalgamo et al., 2002).

CRITERIA FINDING: DISPLAY TECHNOLOGY, IMMERSION AND INTERACTIVITY

While head-mounted technology itself is small, wearable and portable, the environment can be infinitely large, offering a sense of immersion within the environment. For this reason, head-mounted technology is used in the final 3D learning environment for its immersive capabilities, portability, and ability to produce a real-world experience. The Oculus Rift also provided an interactive component, allowing the user to have full control over user movement within the environment.

Interactivity was also designed into the checkpoints within the 3D learning environment. These checkpoints must be activated by user proximity to the checkpoint (user-controlled movement). The checkpoint activity provides the opportunity for user decisions, activities or questions. These checkpoint interactions are further explained in the framework and storyboarding sections.

CRITERIA BACKGROUND: GRAPHIC QUALITY AND FIDELITY: FACTORS IN DESIGNING FOR USER RESPONSE

User response to a particular visualization's content can be altered by the graphic quality and fidelity of the visualization. Graphic quality refers to the texture, illumination and atmospheric conditions of objects and environments within the visualization, which can increase content recognition and concept understanding for users (van Lammeren et al., 2010). Fidelity refers to the degree of realism in an environment, and contains three dimensions: verity, or the degree of realism from the physical to abstract; integration, or the degree of human integration into the environment from batch processing to total inclusion; and interface, or the ranges from natural to artificial within the environment. The degree of realism in rendered 3D images and temporal changes, or changes over time, to the images are the most important visual factors in the fidelity of visualizations (Dalgamo et al., 2002). Within the realm of graphic quality and fidelity is the graphic bias, or 'truthfulness' of the visualization. "Geographical dirtiness" can occur when the visualization creator influences the user by what is or isn't included in a visualization (Pettit et al., 2011). 3D environments are often seen as a truthful and transparent method to convey information, which can often inform or sway public opinion about environmental issues and produce biased responses (Sheppard, 2005). A high level of graphic quality and fidelity, and "truthful" graphics can produce certain user responses about the content of visualizations. Figure 3 is adapted from "Theoretical Effects of Different Types of Landscape Visualization in Stimulating

Perceptions and Behavior in Response to Climate Change" by Sheppard, 2005, explains the relationships between cognitive, affective and behavioral responses to types of visualization stimulus.

DESIGNING FOR COGNITIVE RESPONSES

Cognitive responses are related to the knowledge and understanding of the visualization content by the user. In the context of environmental education, progression from a low state of awareness through environmental action means cognitive processing of information has occurred (Sheppard, 2005). When designing for cognitive responses, the visualization's graphic quality and fidelity are important to consider allowing the user to begin processing information instead of trying to understand or recognize objects within the environment (Sheppard, 2005, van Lammeren et al., 2010).

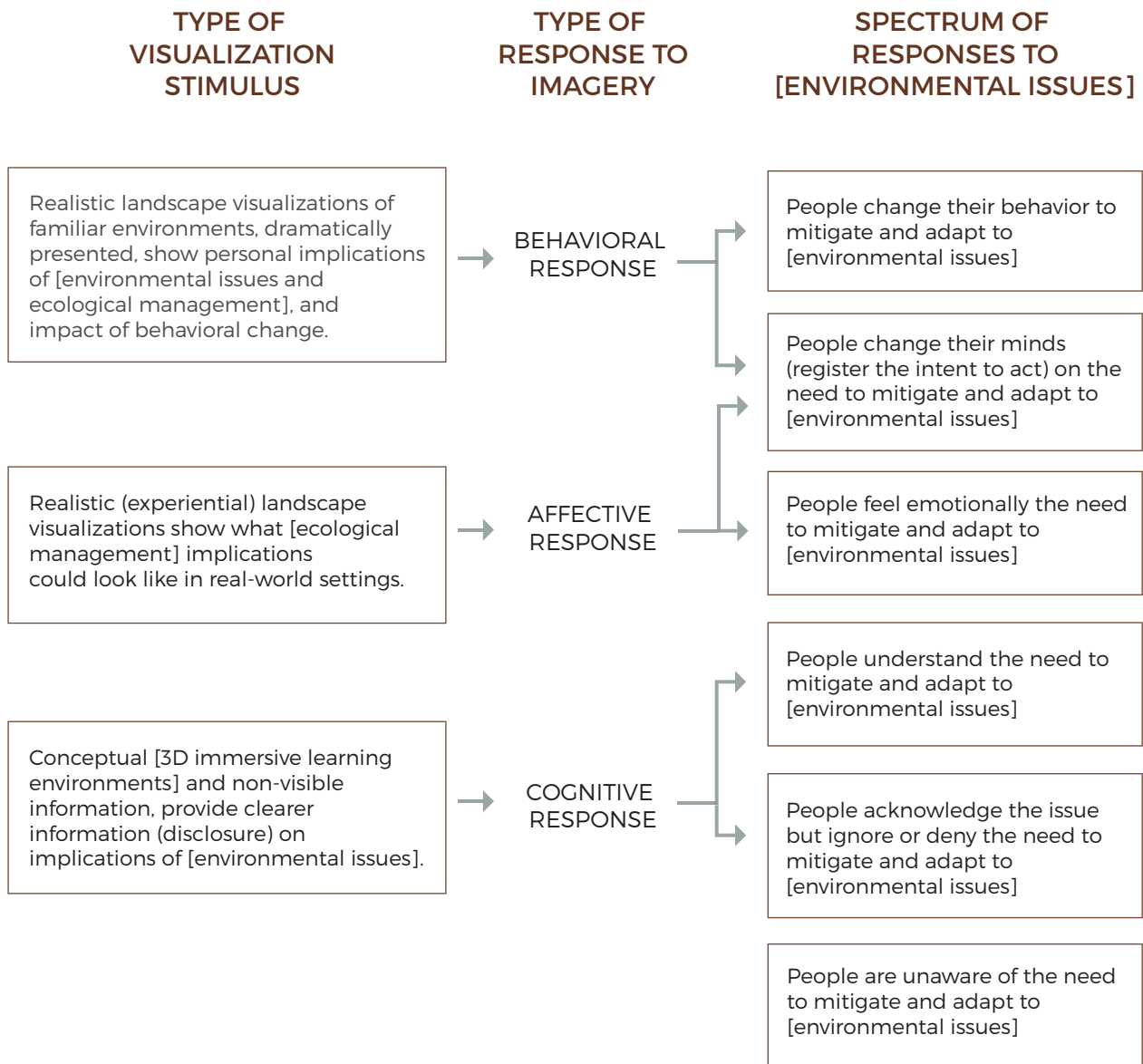


FIGURE 5.5: Theoretical Effects of Different Types of Landscape Visualization in Stimulating Perceptions and Behavior in Response to Climate Change

Source: Adapted from Landscape Visualisation and Climate Change: the Potential for Influencing Perceptions and Behaviour. Sheppard, 2005 <http://www.sciencedirect.com/science/article/pii/S1462901105001188>

DESIGNING FOR AFFECTIVE RESPONSES

Emotions, feelings and attitudes toward visualization content can alter decisions and user mentality about environmental issues. Trying to elicit an affective response from visualization content can be effective and justified to communicate environmental issues, despite potential ethical conflicts. Affective responses to visualizations can be linked to behavioral responses, since emotion, feeling and attitudes can be motivators towards behavior change (Sheppard, 2005). Certain attributes of visualizations can be essential in communicating necessary environmental action through affective responses. Photorealistic imagery can recreate experiential qualities (Appleyard, 1977), making abstract concepts more concrete to visualization users (McKenzie-Mohr and Smith, 1999). Showing relevant and relatable environments, such as local or recognizable areas that are close-to home, and the inclusion of people, animals or recognizable symbols can create a stronger affective response to a particular environmental issue (Nicholson-Cole, 2005; Sheppard, 2004). The immediacy of visualization content, or 'near-term conditions' and long-term conditions that seem closer to the present through speeding up time, and an illustration of consequences of action or inaction can also elicit a strong emotional response (Lorenzoni and Langford, 2001; Furness et al., 1998).

DESIGNING FOR BEHAVIORAL RESPONSES

Both cognitive and affective responses elicited through constructivist learning are necessary for behavioral responses and changes

in environmental action and sustainability (McKenzie-Mohr and Smith, 1999; Maiteny, 2002). However, affective responses are more successful in motivating behavior than cognitive information alone (Sheppard, 2005). The content of visualizations can also create a behavioral response, and in the case of environmental education, emphasizing environmental loss due to inaction can be more persuasive than visualizations that emphasize the benefits of actions (McKenzie-Mohr and Smith, 1999). However, the visual content should be paired with positive results of action in order to not create a feeling of helplessness in the user. Disaster visualizations do not create the same behavioral response as some visualizations because of their unrealistic and melodramatic nature. These visualizations fail to differentiate fact from fiction and can lose credibility with the user. This can make it difficult for the user to connect the real effects of environmental issues with the visualization (Sheppard, 2005). The visualization designer should tailor the content to the audience without compromising the validity of the visualization (Nicholson-Cole, 2005).

Other attributes that may elicit a behavioral response include: qualities that create a sense of presence, engagement that intensifies the experience (Sheppard et al., 2001, Appleyard, 1977); dynamic imagery that provides engagement with the environment or free movement (Orland and Uusitalo, 2001); and interactivity with the environment and/or data display in real-time (Orland and Uusitalo, 2001).

FINDING: GRAPHIC QUALITY FOR THE 3D LEARNING ENVIRONMENT

The final 3D learning environment has been designed to produce cognitive, affective and behavioral responses, depending on the information at each checkpoint. The 3D learning environment has been produced using at least one program with semi-realistic to realistic scene rendering for accurate graphic quality and fidelity, and all information used to create the environment is scientifically-proven to eliminate any bias, or geographic dirtiness.

Measuring the cognitive, affective and behavioral responses is the next step to proving the success of the 3D learning environment. This step is further explored in the evaluation phase.

FRAMEWORK DATA COLLECTION

GIS spatial data was collected from the Konza Prairie Biological Station's Spatial Datasets webpage. This data included elevation data (heightmap created from this data), grazing areas and boundaries, hydrology, soil type, existing trails and roads, burn areas (2000-2007 data), and vegetation transect data. The locations of the Dewey Ranch Barn, Hokanson Homestead and other vegetation sections were located through site visits and Google Earth.

Information for storypoints was gathered through the Konza Prairie's webpage (www.konza.ksu.edu), existing trail guides, and the Konza Environmental Education Program.

FRAMEWORK DATA ORGANIZATION

The spatial datasets and other information gathered were compiled into an Arc Map document, and exported as single maps in one of eight site characterizations: elevation, grazing area, hydrology, soil type, trails & roads, burn areas, culture & history or vegetation. Each base map created the starting point of a framework for the proposed virtual trail loop and ideal checkpoint (pause point) locations. This framework included: the base map with legend for each site characterization with proposed virtual trail loop overlay, storypoint categories, and a more refined breakdown and mapped locations for multiple storypoints. The storypoints were also listed in a matrix of representation options. Once all eight site characterizations were explored using this framework, a final map was created to understand the spatial relationships between

all 47 storypoints (see Figure 5.31). These storypoints were then grouped around final checkpoints based on content and proximity that the user would visit in the 3D environment (see Chapter 6: Telling the Story).

FIGURE 5.6: Framework Basemap
Thumbnails

Source: Source: Adapted from the
Konza Prairie Biological Station
Spatial Dataset, 2014
[http://www.konza.ksu.edu/knz/
pages/data/GISdata.aspx](http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx)



ELEVATION



GRAZING



HYDROLOGY



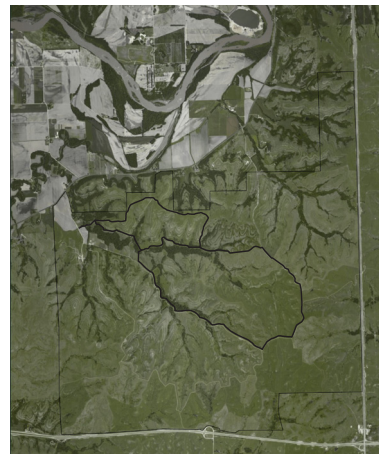
SOILS



TRAILS & ROADS



BURN ZONES



CULTURE & HISTORY



VEGETATION



ELEVATION

Located in the Flint Hills region of northeast Kansas, the Konza Prairie Biological Station encompasses 3,487 hectares of native tallgrass prairie characterized by steep-slopes with shallow limestone soils. Preserved by The Nature Conservancy and Kansas State University, the KPBS is dedicated to a three-fold mission of long-term ecological research, education and prairie conservation.

LEGEND



HIGH 444.98 m

LOW 317.85 m



VIRTUAL TRAIL LOOP

STORYPOINT CATEGORIES

- E1 RIDGELINES
- E2 CUESTA LANDFORM
- E3 LIMESTONE OUTCROP
- E4 BEST VIEWS

FIGURE 5.7: Elevation Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



FIGURE 5.8: Elevation Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
E1.1	Water and wind have sculpted the landscape of the Konza Prairie, as you can see from this ridgeline.	Historical photos fade in over current view, includes text information	Time lapse sequence of landform progression	Weather sequence preset buttons cause time lapse sequence of landform progression
E2.1	Limestone forms the scalloped terraces of the Flint Hills, a distinct feature of the landform here.	Landform section view pop-up with text information	View cuts away into section of landform, includes text overlay	User prompted to trace outline of cuesta landform
E2.2	The landform with steep slopes on one side and gentle slope on the other is called a "cuesta."	Landform section view pop-up with text information		User prompted to trace outline of cuesta landform
E3.1	Limestone from these outcrops was used to build the original buildings on the Konza Prairie.	Text overlay	Outcrop simulation: shows landform before and after outcrop	Activate historical photos,
E4.1	Looking south shows what Kansas looked like 200 years ago. Much of the area was untouched because of the rocky soils that couldn't be cultivated.	Text overlay, fades out for user to look around	User prompted to take a picture of the view using camera option	Camera option: user prompted to take pictures of view
E4.2	This is the best place to view the Konza Prairie.	Text overlay, fades out for user to look around	User prompted to take a picture of the view using camera option	Camera option: user prompted to take pictures of view

FIGURE 5.9: Elevation Representation Options Table



Source: Created by Natalie Webb



GRAZING AREA

The Konza Prairie bison are part of the Konza Prairie Biological Station's long-term ecological research program, which studies the effects of fire and grazing on the prairie ecosystem. The bison live as naturally as possible, with no supplemental help. Grazing is an important ecological process, increasing plant biodiversity and maintaining the character of the prairie ecosystem.

LEGEND

-  BISON GRAZING BOUNDARY
-  VIRTUAL TRAIL LOOP

STORYPOINT CATEGORIES

- G1 HISTORY OF THE BISON
- G2 BISON GRAZING AREA
- G3 ECOLOGICAL MANAGEMENT TOOL

FIGURE 5.10: Grazing Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



FIGURE 5.11: Grazing Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
G1.1	Native Americans hunted the bison and used almost every part of the animal for food, tools, and clothing.	Historical photos fade in over current view, includes text information	Historical photos fade in over current view, user prompted to decide how to use different parts of the bison	User prompted to go on bison hunt and decide how to use bison; activates historical photos or simulation
G1.2	Millions of bison once roamed and grazed on the Great Plains, but were almost driven to extinction by the pioneers in the 1880s.	Historical photos fade in over current view, includes text information	Historical photos fade in over current view, user prompted to walk around bison	
G1.3	This is an ancient bison wallow. The impact the bison left on the prairie can be seen in the plant biodiversity that grows in the wallow, compared to nearby prairie.	Text overlay, user prompted to walk around bison wallow and observe	Bison sequence shows bison using wallow, user prompted to take photos	Camera option: user prompted to take pictures of bison
G2.1	There's about 300 bison here that are part of the long-term ecological research program of the Konza Prairie.	Photo overlay showing current bison herd, text information	Bison sequence, user prompts determine bison interaction and prairie succession sequence	User prompted to answer evaluation questions about prairie succession, user controls bison grazing
G3.1	Crazing is an important ecological process for the prairie, maintaining the grassland character of the Konza Prairie.	Photo overlay showing prairie succession with grazing vs. no grazing, text information	Bison sequence, user prompts determine bison interaction and prairie succession sequence	User prompted to answer evaluation questions about prairie succession, user controls bison grazing
G3.2	Bison can remove about 54% of yearly plant growth. Plant diversity is higher in bison pastures, compared to cattle pastures.	Photo overlay showing prairie succession with grazing vs. no grazing, text information	Bison sequence, user prompts determine bison interaction and prairie succession sequence	User prompted to answer evaluation questions about prairie succession, user controls bison grazing

FIGURE 5.12: Grazing Representation Options Table

Source: Created by Natalie Webb



HYDROLOGY

The Konza Prairie has two main streams that flow throughout the site. One stream, Kings Creek, is considered to be in pristine condition and is studied in comparison to other human-impacted streams, according to the U.S. Geological Survey.

LEGEND

- HYDROLOGY
- STREAM GAUGE STATIONS
- VIRTUAL TRAIL LOOP

STORYPOINT CATEGORIES

- H1 KINGS CREEK
- H2 EROSION FROM STREAM CUTTING
- H3 WATER & VEGETATION

FIGURE 5.13: Hydrology Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
H1.1	Kings Creek is one of the two major streams on the Konza Prairie.	Text overlay	Pop-up map overlay shows highlighted streams	
H1.2	The area and trees surrounding the creek is called a "riparian area."	Text overlay, user prompted to walk around riparian area.	User prompted to take plant samples, predetermined plants are highlighted, text overlay	
H1.3	Kings Creek is spring-fed and in pristine condition according to the USGS. The water is filtered by prairie sod and limestone layers.	Text overlay	Water filtration simulation, shows prairie sod and limestone layers	
H2.1	This area has been eroded by natural stream cutting. Most of the erosion happens slowly, but "flash floods" can alter the prairie stream dramatically.	Historical photos fade in over current view, includes text overlay	Time lapse sequence of stream bank erosion	User prompted to select weather preset buttons, watch weather sequence and stream bank erosion
H3.1	About 7% of the Konza Prairie is forested and is concentrated around water sources.	Text overlay	Multiple choice question(s)	Multiple choice question(s) about hydrology
H3.2	Cottonwoods and Willow trees grow around the water sources. Early pioneers knew if they found these trees, they could find water.	Text overlay	Historical photos fade in over current view showing pioneers, includes text overlay	

FIGURE 5.14: Hydrology Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

FIGURE 5.15: Hydrology Representation Options Table


















Source: Created by Natalie Webb



SOIL TYPE

The Konza Prairie is characterized by shallow, rocky soils on top of limestone. For this reason, much of the prairie cannot be cultivated. Thin, gray layers of flint run through the limestone rock, hence the name the “Flint Hills.” Cracks in the limestone rock allow water to seep in, producing bands of vegetation on the slopes.

LEGEND

 AD - Alluvial	 IE - Ivan
 BF - Benfield	 IV - Ivan
 BK - Breaks-Alluvial	 RD - Reading
 CH - Chase	 RE - Reading
 CS - Clime	 ST - Stony steep
 DR - Dwight	 TS - Tully
 IC - Irwin	 TU - Tully
 ID - Irwin	 TV - Tully
 VIRTUAL TRAIL LOOP	

STORYPOINT CATEGORIES

- S1 SOILS OVERVIEW
- S2 LIMESTONE BELOW SOILS
- S3 BANDS OF ROCKY SOIL, LIMESTONE & FLINT

FIGURE 5.16: Soils Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
S1.1	The soils on the Konza Prairie are made from weathered limestone dust from the Ice Age and organic remains of plants.	Text overlay	Time lapse sequence of soil deposits (from Ice Age erosion and plant build up, to present)	
S1.2	Kings Creek's far-side bank is eroded away, showing the deep lowland soils.	Photo overlay shows King's Creek's soil layers, includes text information	Time lapse sequence of stream bank erosion	User prompted to select soil layer in evaluation questions based on previous information
S2.1	The limestone below the shallow soils came from an ancient ocean that covered the Konza Prairie about 250 million years ago.	Scene pop-up with text overlay	Time lapse sequence of ocean to dry land, showing limestone deposits	Checkpoint activation causes ocean to dry land sequence
S3.1	On the ridge, you can see the bands of rocky soil, limestone and flint. That's where the Flint Hills got their name.	Section view pop-up with text overlay	Section view landform cut away, includes text overlay	Multiple choice question(s) about how Flint Hills got their name

FIGURE 5.17: Soils Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

FIGURE 5.18: Soil Type Representation Options Table

Source: Created by Natalie Webb



TRAILS & ROADS

The Konza Prairie has three main trail loops open to the public: Nature Trail (2.5 miles), Kings Creek Trail (4.4 miles), and the Godwin Hill Loop (6.0 miles). These trails follow much of Kings Creek, which would have provided the early settlers following these trails with water and shade.

LEGEND

- WALKING TRAILS
- VEHICULAR ROADS
- VIRTUAL TRAIL LOOP

STORYPOINT CATEGORIES

- T1 NATURE TRAIL LOCATIONS
- T2 REASONS FOR TRAIL LOCATION
- T3 TRAIL RESTRICTIONS

FIGURE 5.19: Trails & Roads Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
T1.1	This is the first Nature Trail loop of 2.6 miles. This trail is the shortest on the Konza Prairie and is open to visitors.	Text overlay	Map overlay with highlighted trail	User can explore this trail with checkpoints
T1.2	This is the second loop of the Nature Trail, and is about 3.3 miles long. This trail is open to visitors.	Text overlay	Map overlay with highlighted trail	User can explore this trail with checkpoints
T1.3	This is the longest loop of the Nature Trail, and is about 6 miles long. The trail is open to visitors, and takes about 4 hours to hike when on the Konza Prairie.	Text overlay	Map overlay with highlighted trail	User can explore this trail with checkpoints
T2.1	The trails and roads are located along path that expose visitors to diverse areas of the Konza Prairie.	Text overlay	Map overlay with highlighted trail	
T3.1	This trail loop is usually open to researchers only, and includes bison grazing areas.	Text overlay	Map overlay with highlighted trail	User can explore this trail with checkpoints

FIGURE 5.20: Trails & Roads Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

FIGURE 5.21: Trails & Roads Representation Options Table



Source: Created by Natalie Webb



BURN AREAS

Fire is essential in the maintenance of prairie ecosystems. Part of the long-term ecological research conducted at the Konza Prairie, prairie fires are now managed by people to maintain the character of mesic grasslands. Sections of the Konza Prairie are burned annually, or every 2, 4 or 20 years.

LEGEND

-  BURN ZONES (2007 DATA)
-  VIRTUAL TRAIL LOOP

STORYPOINT CATEGORIES

- B1 HISTORY OF PRAIRIE BURNING
- B2 ECOLOGICAL MANAGEMENT TOOL
- B3 FIRE-TOLERANT VEGETATION
- B4 FIREGUARDS

FIGURE 5.22: Burn Zone Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



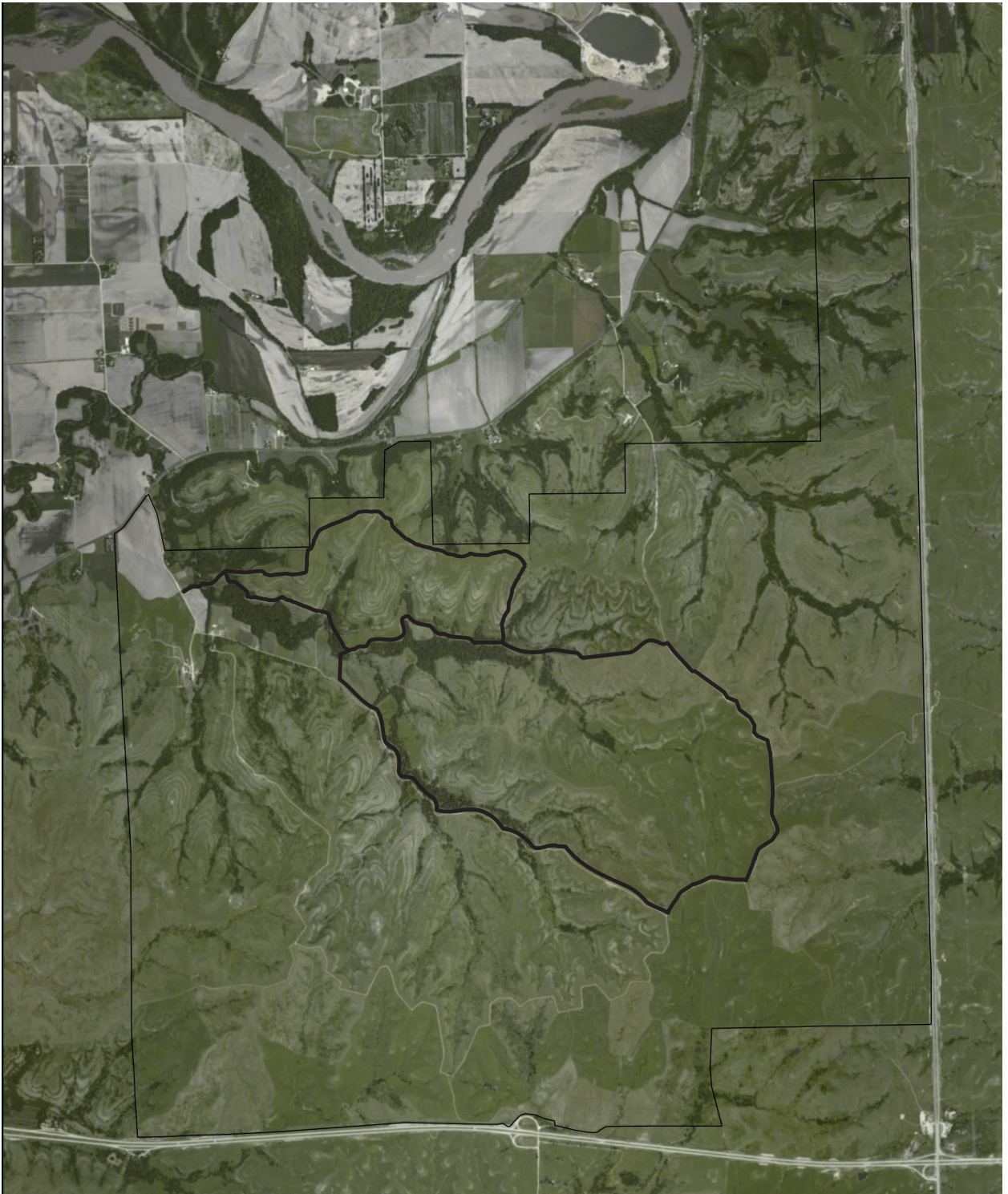
FIGURE 5.23: Burn Zone Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
B1.1	Prairie fires used to be a naturally occurring phenomena, but are now regulated by people to achieve the same outcome.	Burning photos fade in over current view, includes text information	Weather/natural phenomena simulation causes prairie fires	
B2.1	Prairie burning is an important ecological management tool, keeping woody shrubs and trees from taking over the grassland character. Burning is part of the LTER program at the Konza Prairie.	Photo overlay showing prairie succession of burning vs. no burning, text information	Prairie succession simulation with pause points at burning intervals	Evaluation question ("Burn the prairie?")
B2.2	There's a significant difference between areas burned every year, and every 10 years as you can see here. Areas of the Konza are burned annually, or every 2, 4, 10 or 20 years.	Photo overlay showing prairie success of burning annually vs. every 10 years, text information	Burning simulation in current view, evaluation questions introduced to cause prairie succession and fire interaction	Evaluation question ("Burn the prairie?")
B3.1	The Konza Prairie is dominated by fire-tolerant grasses.	Photo overlay showing prairie grasses, includes text information	Prairie succession simulation of burning annually vs. burning every 10 years, text information	
B4.1	These are "fireguards," or roads and mowed grass that separate areas with different burning treatments.	Text overlay	Pop-up map overlay shows highlighted fireguards	

FIGURE 5.24: Burn Zone Representation Options Table

Source: Created by Natalie Webb



CULTURE & HISTORY

The Konza Prairie was originally a 95-acre, Swedish-settled homestead from the 1870s. The Hokanson brothers built the homestead from nearby quarried limestone. The homestead was successful, unlike other homesteads in the area, due to nearby water.

Now jointly owned by The Nature Conservancy and Kansas State University, the Konza Prairie is a station for researchers from around the world.

LEGEND

- HOKANSON HOMESTEAD
- DEWEY RANCH BARN
- VIRTUAL TRAIL LOOP

STORYPOINT CATEGORIES

- C1 HISTORY OF THE KONZA PRAIRIE
- C2 HOKANSON HOMESTEAD
- C3 DEWEY RANCH BARN
- C4 WILDLIFE ON THE HOMESTEAD TRAIL
- C5 LIMESTONE LEDGE QUARRY

FIGURE 5.25: Culture & History Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



FIGURE 5.26: Culture & History Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
C1.1	The Konza Prairie is jointly owned by The Nature Conservancy and Kansas State University	Text overlay		
C2.1	The Konza Prairie was originally a 95-acre Swedish-settled homestead from the 1870s, settled by the Hokanson brothers.	Historical photos fade in over current scene, includes text information	Historical photos fade in over current scene, includes text information and multiple choice questions	
C3.1	The Hokanson Homestead was surrounded by the Dewey Cattle Company (1910), who owned the Dewey Ranch Barn.	Text overlay	Historical photos fade in over current scene, includes text information and map overlay of homestead and barn	
C3.2	Abandoned feed troughs suggest that the area may have been used as a feedlot for cattle, but is now abandoned pasture.	Historical photos fade in over current scene, includes text information		
C4.1	Deer, turkey and birds heavily populate the Homestead Trail, and can be seen at the wildlife observation lean-to behind the barn.	Wildlife photos fade in over current scene, includes text information	User prompted to take a picture of the view using camera option	Camera option: user prompted to take pictures of view
C5.1	Limestone was quarried from nearby limestone ledges to build these stone buildings.	Historical photos fade in over current scene, includes text information	Outcrop simulation: shows landform before and after limestone was quarried	Building component: user prompted to remove limestone from quarry and placed into building framework

FIGURE 5.27: Culture & History Representation Options Table

Source: Created by Natalie Webb



VEGETATION

The Konza Prairie consists of mostly tallgrass prairie plants, and is known as a 'mesic grassland.' Much of the Konza Prairie's vegetation is underground because of their extensive root systems, making them very drought tolerant.

STORYPOINT CATEGORIES

- V1 TALLGRASS PRAIRIE
- V2 RESEARCH FIELDS
- V3 SHORTGRASS PRAIRIE
- V4 PRAIRIE GRASS ROOT SYSTEM
- V5 PRAIRIE WILDFLOWERS

FIGURE 5.28: Vegetation Basemap

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>



FIGURE 5.29: Vegetation Basemap with Storypoints

Source: Source: Adapted from the Konza Prairie Biological Station Spatial Dataset, 2014
<http://www.konza.ksu.edu/knz/pages/data/GISdata.aspx>

STORYPOINT	DESCRIPTION	DISPLAY OPTION (TEXT/PHOTO OVERLAYS)	DISPLAY OPTION (CHANGING CONDITIONS)	INTERACTIVE GAME COMPONENT OPTION
V1.1	The Konza Prairie is an 8,600 acre area of native tallgrass prairie preserved by The Nature Conservancy and managed by the Division of Biology at K-State.	Text overlay		
V1.2	Dominant tallgrass prairie grass can be seen here, like Big Bluestem, Indian grass, Little Bluestem and Switchgrass.	Photo overlay showing dominant tallgrass prairie grasses, includes text information	User prompted to take plant samples, predetermined plants are highlighted, text overlay	
V3.1	Shortgrass prairie species grow here, like blue and hairy grama grasses.	Photo overlay showing dominant shortgrass prairie grasses, includes text information	User prompted to take plant samples, predetermined plants are highlighted, text overlay	
V4.1	Grasses on the Konza Prairie survive drought conditions with their extensive root systems.	Photo overlay showing dominant prairie grasses roots, includes text information	User prompted to take plant samples, predetermined plants are highlighted, text overlay	Multiple choice question (How deep can the root system of the prairie get?)
V4.2	Big Bluestem grasses can have root systems up to 12 feet long.	Photo overlay showing dominant prairie grasses roots, includes text information	User prompted to take plant samples, predetermined plants are highlighted, text overlay	
V5.1	About 600 species of prairie wildflowers bloom in the spring and summer on the Konza Prairie.	Photo overlay showing prairie wildflowers includes text information	User prompted to take plant samples, predetermined plants are highlighted, text overlay	Seasonal sequence preset buttons

FIGURE 5.30: Vegetation Representation Options Table

Source: Created by Natalie Webb



FIGURE 5.31: Determining Checkpoints from Array of Storypoints

Source: Created by Natalie Webb

DETERMINING CHECKPOINTS

Compiling all the storypoints from the framework tables on a single map showed spatial relationships between the points. By grouping these storypoints together based on spatial proximity and information relevance, 16 trail checkpoints (pause points) were established. These checkpoints contain one

to four different storypoints, creating more informative checkpoints. The combination also made the 3D learning environment much more feasible for a user to explore by condensing the 47 storypoints into 16 checkpoint trail stops.

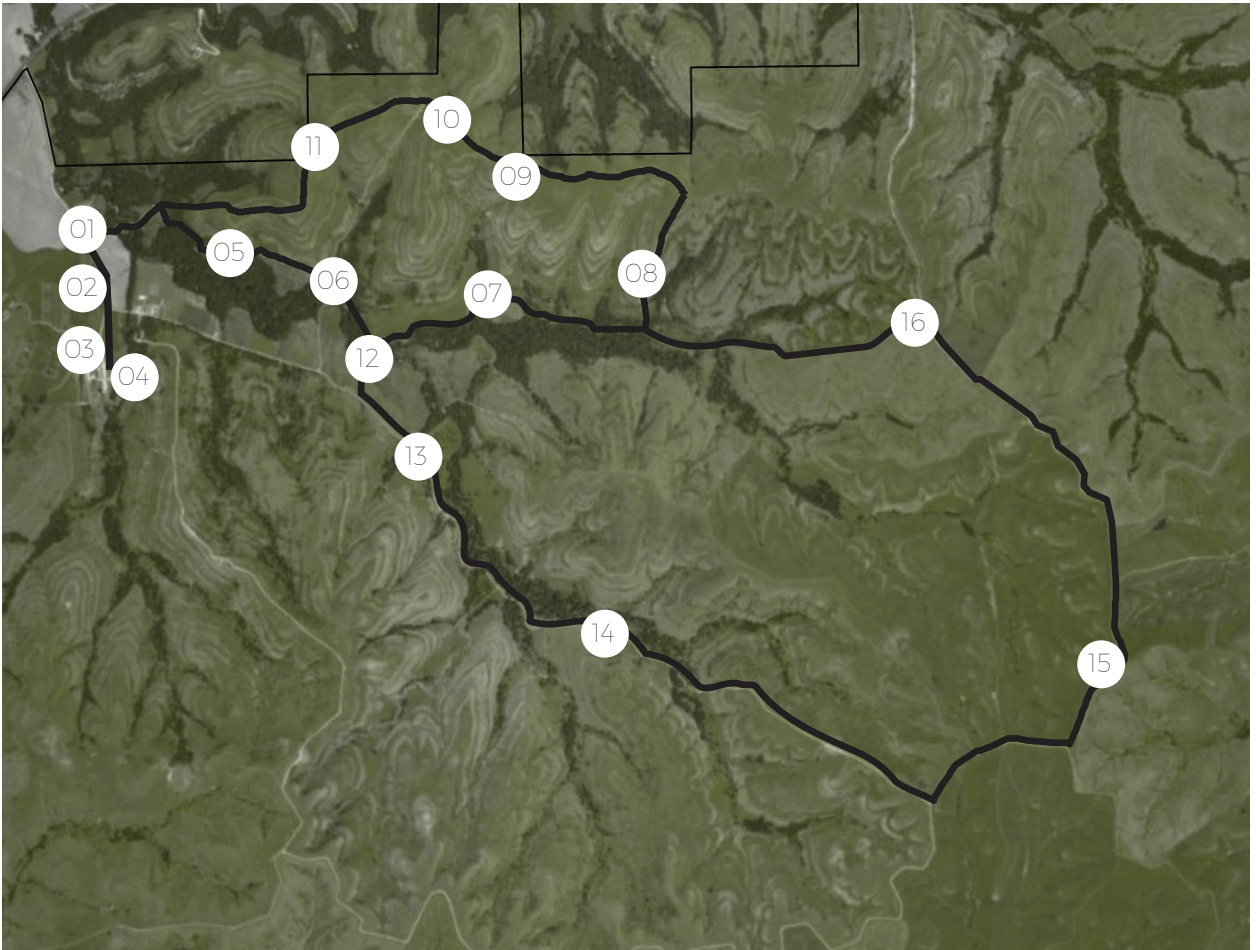


FIGURE 5.32: Checkpoint Map with Virtual Trail

Source: Created by Natalie Webb



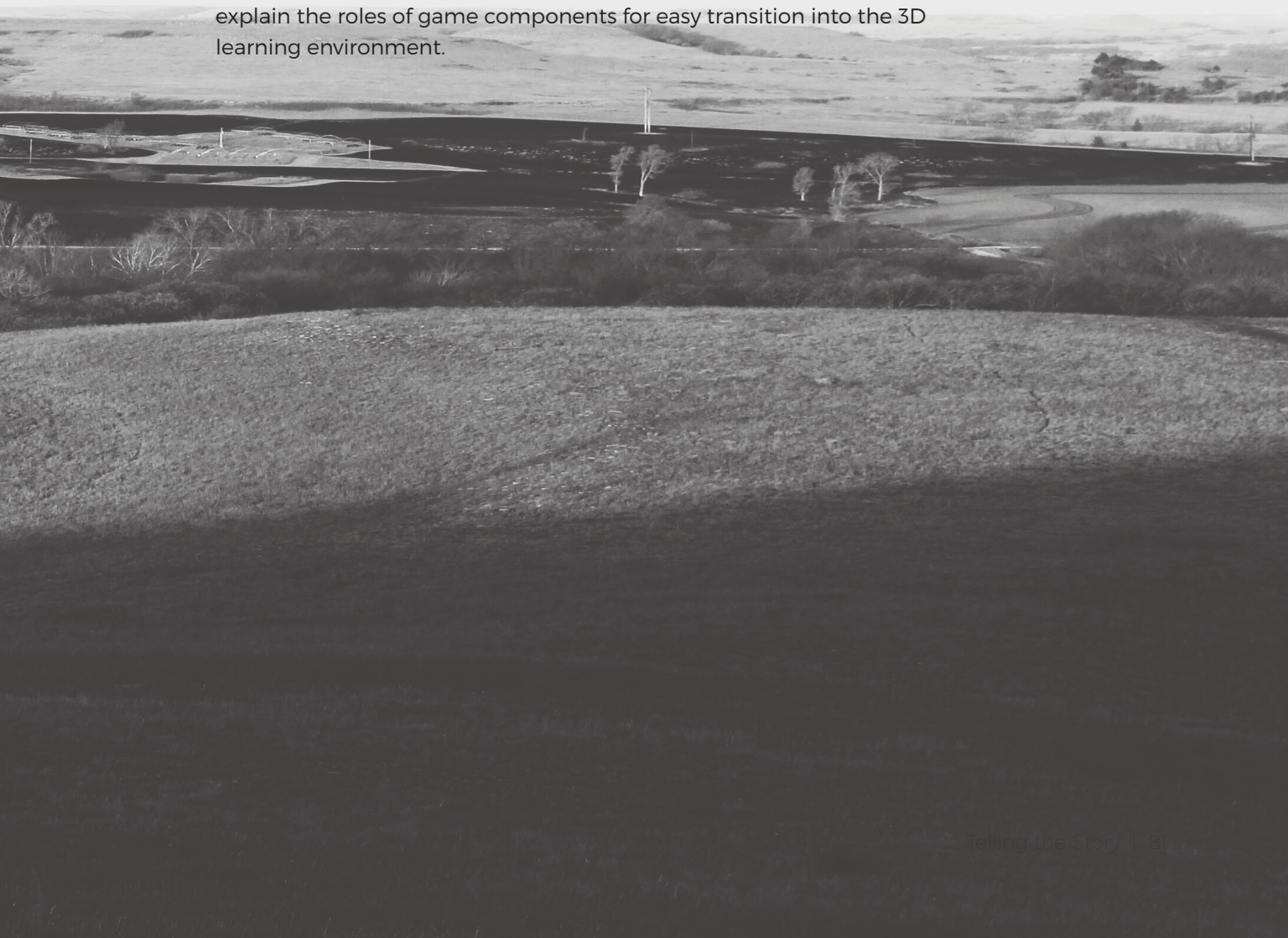
06 **TELLING THE STORY**

UNDERSTANDING THE GAME

Game interface and storyboarding are two main components of designing the Konza Prairie 3D learning environment.

The game interface was designed to contrast with the photorealism of the 3D learning environment. Components like the introduction and instructions screen, map, backpack, control center and icons are inspired by a summer camp, flat vector style to appeal to the target audience.

The following hardware component and user interface introductions explain the roles of game components for easy transition into the 3D learning environment.



EQUIPMENT

OCULUS RIFT

The Oculus Rift virtual reality headset is the preferred display technology to be used in the Konza Prairie 3D learning environment. Although this game can be viewed on a computer screen or various other screens, the Oculus Rift provides visual immersion in the virtual environment.



GAME CONTROLLER

A game controller is used to navigate the 3D learning environment, using the joystick to move forward and backward. Front triggers and buttons activate various interactive components in the environment, as described in Figure 6.1.



COMPUTER

A high-powered computer is necessary to host the game, and engage the Oculus Rift, game controller and headphones.



HEADPHONES

Headphones are recommended to achieve the fully immersive experience, but not necessary for the virtual environment to function.



NAVIGATING THE CONTROLLER

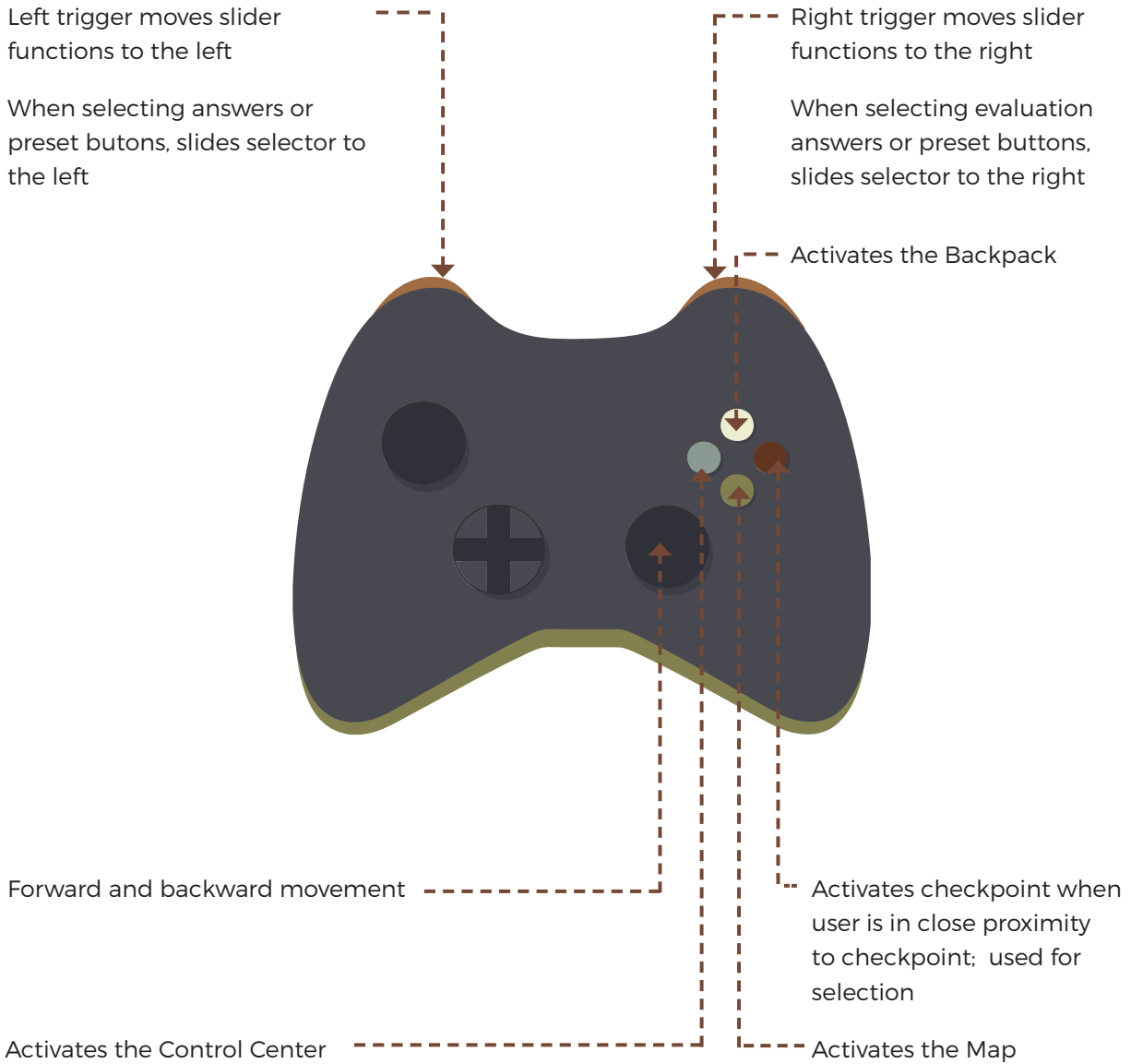


FIGURE 6.1: Navigating the Controller

Source: Created by Natalie Webb



FIGURE 6.2: Navigating the Virtual Scene

Source: Created by Natalie Webb



- - - - The Control Center icon is available in the upper left-hand corner, and activates the Control Center menu where time, weather, season and camera views are stored.
- - - - The Backpack icon is available in the upper left-hand corner, and activates the Backpack menu where badges and photos are stored.
- - - - The Location icon is available in the upper left-hand corner, and activates the Map menu for user and checkpoint locations.
- - - - The wayfinding points appear as floating orange spheres, guiding the user through the virtual trail loop. Two points are displayed at a time. When the user passes through one wayfinding point, another appears along the virtual trail.
- - - - The checkpoints appear as floating light blue spheres, activated once the user is within close proximity to the checkpoint. These points are displayed at all times along the virtual trail loop. Once the user has completed a checkpoint, the sphere turns dark blue.

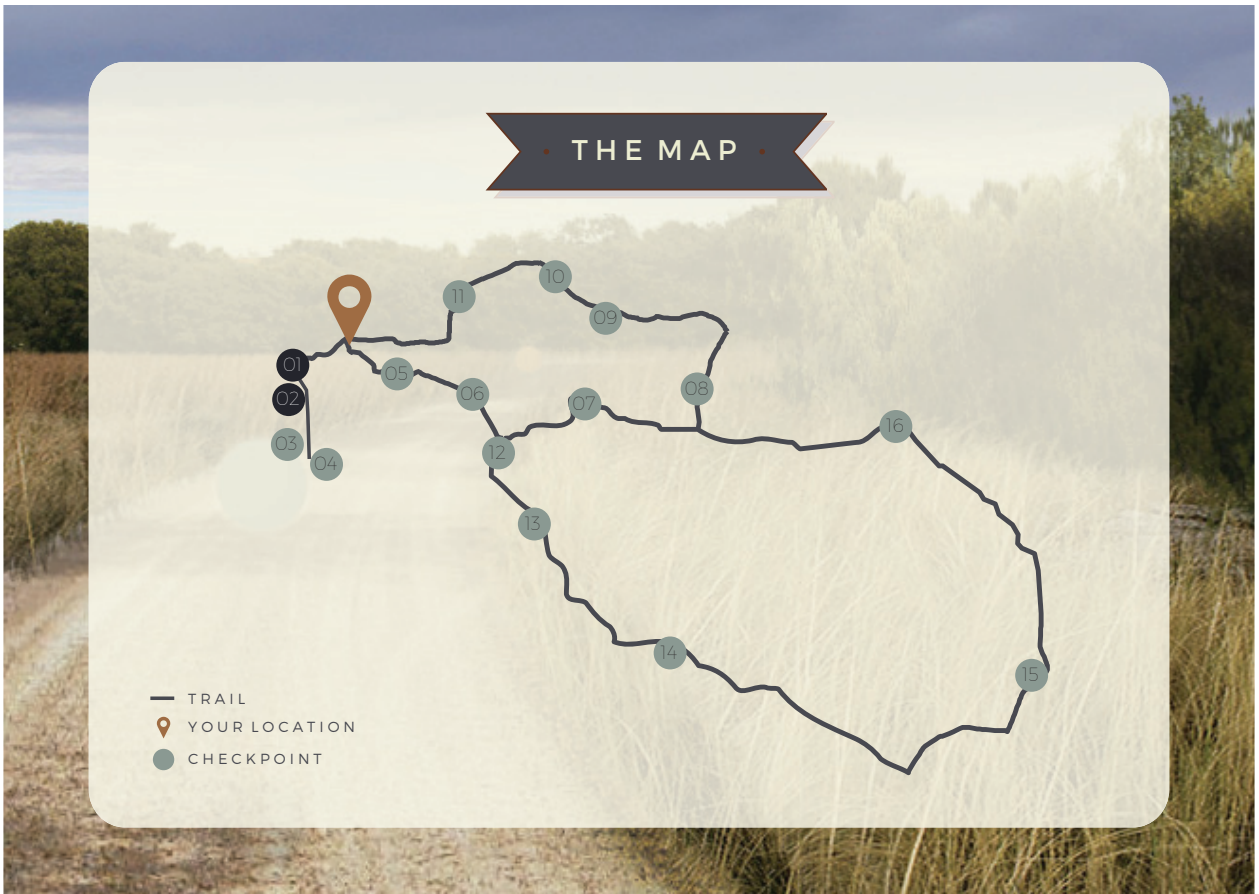
NAVIGATION

WAYFINDING & MAPS

The user is guided through the virtual trail loop by wayfinding points, or floating orange spheres that appear two at a time along the trail. Once the user has passed through a wayfinding point, another appears ahead along the virtual trail. The user can access the full virtual trail, checkpoint locations and user location in the Map (see Figure 6.3).

CHECKPOINTS

Checkpoints appear as floating light blue spheres along the trail loop. These points can be activated once the user is in close proximity to the checkpoint. Active checkpoints appear as light blue circles on the Map and in the environment. Once the checkpoint has been completed, it appears as a dark blue on the Map and in the environment.



WAYFINDING POINT

Orange points guide user through the game on the virtual trail loop



ACTIVE CHECKPOINT

Light blue points are checkpoints the user has not completed



INACTIVE CHECKPOINT

Dark blue points are checkpoints the user has completed

FIGURE 6.3: Map User Menu, Wayfinding Point System and Checkpoint System

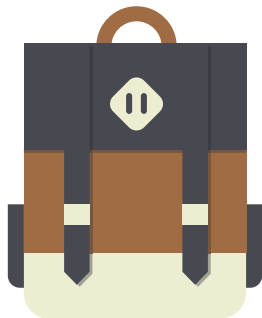
Source: Created by Natalie Webb

THE BACKPACK

The Backpack acts as virtual storage for items collected during checkpoints, such as badges and photos. Represented by a backpack icon in the main screen view and accessible to the user at anytime, the Backpack visually organizes information for user to keep track of their progress in the environment.

When the user collects a badge at a checkpoint, the badge automatically appears in the Backpack under “Badges.” Multiples of the same badge appear as a single badge with the total number collected at the lower right hand corner of the badge (see Figure 6.4).

The Backpack also provides a space to review information at the end of the game. When the user returns to the entry checkpoint, a backpack overview sequence begins. Each photo and badge is recapped with supplemental information about the focus topic. A final evaluation sequence occurs using Modified Environmental Awareness Scale questions to evaluate the users environmental awareness.



THE BACKPACK

The Backpack icon is available to the user in the main screen, and activated by the game controller buttons.

FIGURE 6.4: Backpack User Menu, Badges and Photos

Source: Created by Natalie Webb

CONTROL CENTER

The Control Center (Figure 6.5) houses the Time of Day, Season, Camera and Weather preset buttons. Control over these aspects of the 3D learning environment allows the user to customize the environment and experience the Konza Prairie in a variety of circumstances. This customization provides a crucial and unique aspect of the 3D learning environment, since it would take the user much longer to physically experience all of the different combinations of weather, time, and season while at the Konza Prairie. The manipulation of each aspect of the environment appeals to the constructivist learning theory, allowing the user to create their own learning environment and also creating a unique environment each time the game is played.



CONTROL CENTER

The Control Center icon is available to the user in the main screen, and activated by the game controller buttons.

FIGURE 6.5: Control Center User Menu

Source: Created by Natalie Webb

GAME MODE

There are two game modes in the Konza Prairie 3D Learning Environment: “Full Game” and “Badge Completion” modes. The “Full Game” mode gives the user access to all 16 checkpoints and full visualization content. The “Badge Completion” mode separates the checkpoints into five separate badges to focus the checkpoint content: Land, Prairie Fire, Grazing, Plant and History.

AUDITORY MODE

ENVIRONMENTAL SOUNDS

Sound and auditory information in the environment provide environmental cues and context for the virtual prairie. Environmental sounds are season, time, and weather specific. For example, environmental sounds during a spring thunderstorm would include rain, wind and thunder. Environmental sounds during a fall night would include crickets chirping, grasses rustling and a slight breeze. These environmental sounds should be based on the actual sounds of the Konza Prairie, seasonal and weather aspects, and should consider the time of day.

NARRATION

In the “Game Mode” menu, the user may choose whether to have text narration during the checkpoint sequences. This may help auditory learners process the information more efficiently.



FIGURE 6.6: Game Mode User Menu

Source: Created by Natalie Webb

EARNING BADGES

There are five badge categories to be earned throughout the game: land, plant, grazing, history and prairie burning. Checkpoints are associated with one of these five badges, which the user can earn if evaluation questions are answered correctly during that checkpoint. Checkpoints can be focused into levels based on topic using the badge system, allowing the user to complete all checkpoints associated with a specific badge instead of the full game (see Evaluating Environmental Learning: Level-Based Evaluation).

When the user earns a badge for answering an evaluation question correctly, the corresponding badge is collected in the Backpack. All badges are recapped at the end backpack overview sequence, providing an opportunity to review and provide supplemental information to the user.

FIGURE 6.7: Badges

Source: Created by Natalie Webb



The land badge covers topics such as landform characteristics and hydrology, highlighting the cuestas, soil composition, limestone bedrock and Kings Creek.



The prairie fire badge covers topics such as prairie burning for ecological management, fire as a natural phenomena, and burning to retain the character of the Konza Prairie.



The plant badge covers topics such as different prairie vegetation found on the Konza Prairie and fire-tolerant grasses.



The history badge covers topics such as the Hokanson Homestead, Dewey Ranch Barn, and Native Americans on the Konza Prairie.



The grazing badge covers topics such as bison on the Konza Prairie and grazing as an ecological management tool.

VIEWS & PHOTOS



The Camera option icon (Figure 6.8) allows the user to take a photo during the checkpoint or scene. When this option is selected, the view mimics a camera lens while the user sets up the photo. When the user takes a photo, the screen flashes white to mimic a flash and the photo is then stored in the Backpack.



The Historical View icon (Figure 6.9) allows the user to view the checkpoint scene with historical photograph overlay. This view is particularly useful at checkpoints where the History badge is available. When this option is selected, the scene has a sepia overlay with a historical photograph of the current scene. This photo is then stored in the Backpack.



The photographs taken using these two camera views are stored in the Backpack as Polaroid icons (Figure 6.10), and are also available for the user to view at any time.

SEASON PRESET OPTIONS



FIGURE 6.11: Seasonal Presets

Source: Created by Natalie Webb

TIME OF DAY SEQUENCE

Time of Day sequence is an interactive component within the Konza Prairie 3D learning environment. The timeline (Figure 6.7) is a manual slider from 12 am to 12 pm to 12 am, giving the user options to experience the environment at all times of the day.

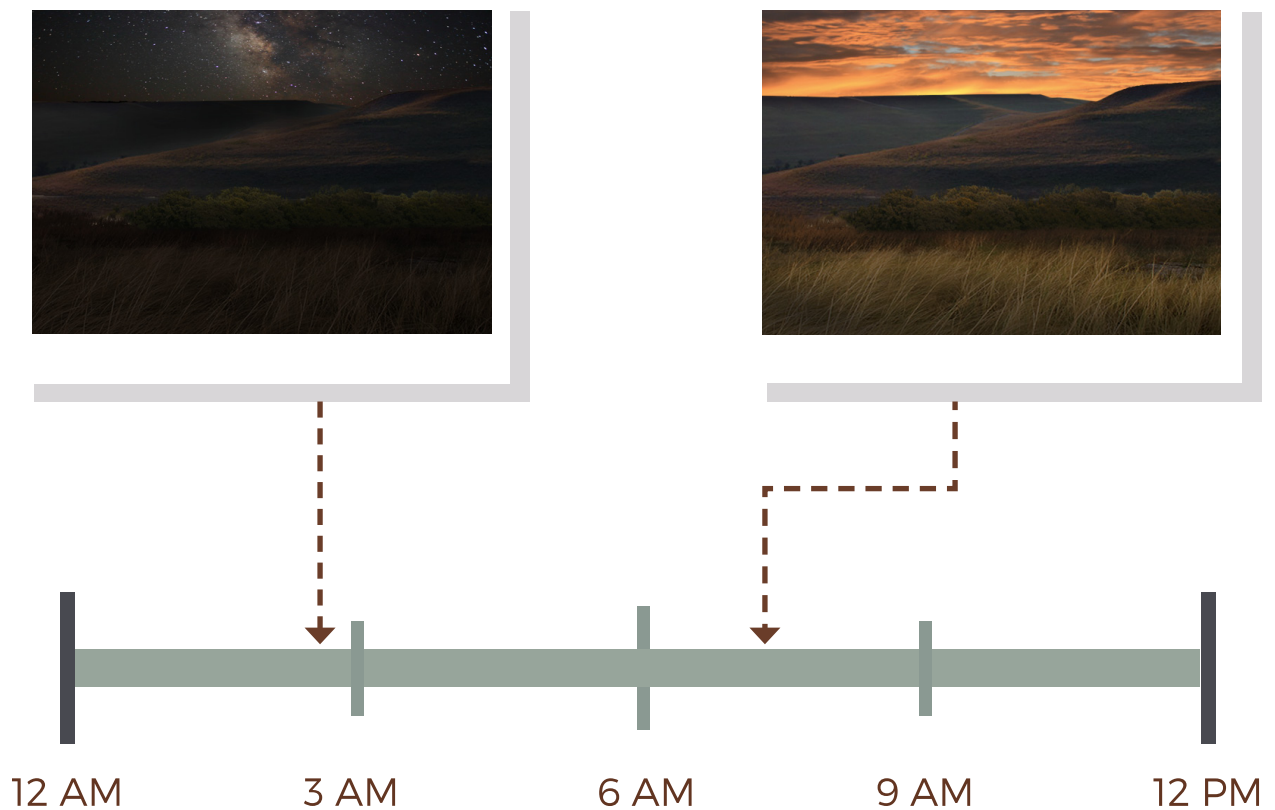
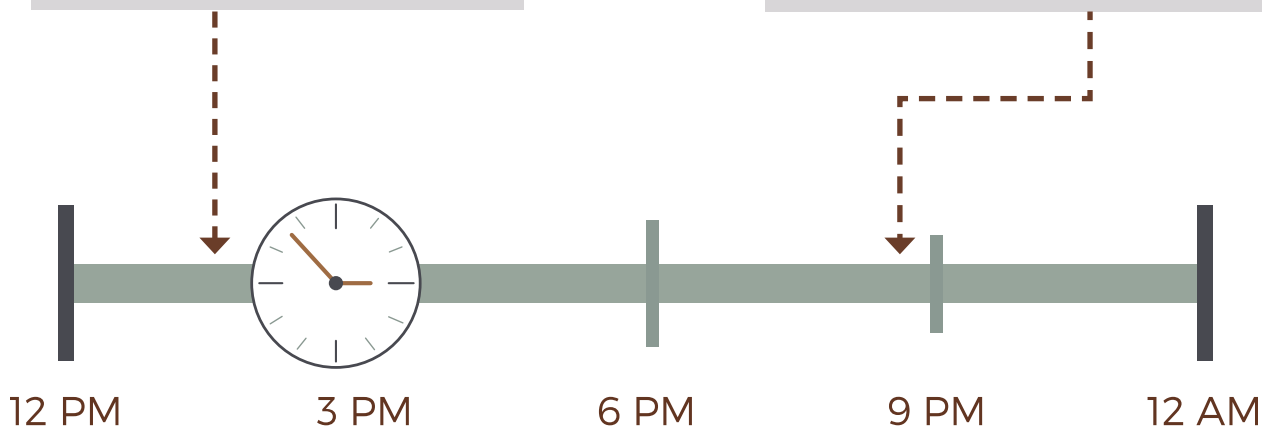
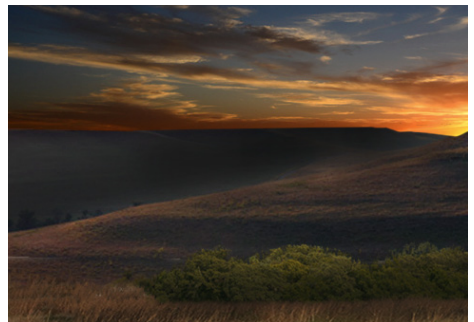


FIGURE 6.12: Time of Day Sequence

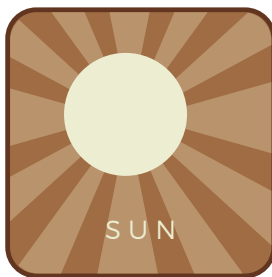
Source: Created by Natalie Webb



WEATHER PRESET OPTIONS

There are six weather preset options in the game: sun, clouds, rain, wind, thunderstorm, and snow. Some checkpoints incorporate the weather sequence as an interactive component, but weather presets are available at any time during the exploration.

Weather presets (Figure 6.13) have parameters that restrict them to the appropriate seasons. For example, the “snow” preset cannot be selected with the “summer” seasonal preset.



The “sun” weather preset triggers a clear, sunny sky that can be activated during all seasons and times of the day. If this preset is chosen during a nighttime hour, it overrides the time slider and changes to a daytime hour.



The “clouds” weather preset triggers cloud cover in the sky with three coverage levels: dispersed clouds, partially cloudy and overcast. This preset can be activated during all seasons and times of day.



The “rain” weather preset triggers light rain and automatically triggers the “clouds” preset to overcast. This preset can be activated in the spring, summer and fall seasons, and during all times of day.



The “wind” weather preset triggers one of four wind speeds: breezy, windy, very windy, and tornado. This preset can be activated during all seasons and times of day, but the tornado setting can only be activated in spring and summer seasons.



The “thunderstorm” weather preset triggers heavy rain, thunder, lightning, and dark clouds. This preset can be activated during all times of day, and in spring, summer and fall seasons.



The “snow” weather preset triggers medium snow fall and accumulation, and can be triggered at all times of day but only during the winter season.

STORYBOARDING

Storyboards are graphic organizers and pre-visualizing tools that can sequence information and illustrations, usually used in the animation process. These scenes are composed of still images that serve as the visualization blueprints, to later be used as guidelines for creating the final visualization.

Storyboards for the Konza Prairie 3D learning environment are used to visually explore the 16 checkpoints located along the virtual trail loop, displaying the user experience at each point. Each storyboarding checkpoint includes: the scene as the user approaches the checkpoint, scene notes, story point information included at the specific checkpoint (from the base map frameworks in Concepts & Understanding), and 3-4 subsequent scenes illustrating the checkpoint activity.



OPENING SCENE: AERIAL FLY-IN

Game begins with fly-in sequence

Approach from the northwest corner of the Konza Prairie



AERIAL FLY-IN THROUGH CLOUD COVER:

Continued fly-in sequence passes through cloud cover

Cloud cover provides transition between less detailed and more detailed landscape scene



AERIAL FLY-IN:

Fly-in approach drops user at Checkpoint 01 of the virtual trail

01 CHECKPOINT

ENTRY POINT SEQUENCE

CONTENT:

C1.1 - The Konza Prairie is jointly owned by The Nature Conservancy and Kansas State University

V1.1 - The Konza Prairie is an 8,600 acre area of native tallgrass prairie, preserved by the Nature Conservancy and managed by the Biology Division of Kansas State University.

T2.1 - The trails and roads are located along paths that expose visitors to diverse areas on the Konza Prairie

SCENE NOTES:

Beginning sequence of game

Includes equipment instructions screen

Map instructions

Backpack instructions

Control Center Instructions

Game mode & objective instructions





WELCOME SCREEN:

"Welcome to the Konza Prairie: A 3D Learning Environment"

Scene immediately after fly-in sequence

Informative Content Screen: storypoint content C1.1, V1.1, T2.1



EQUIPMENT INSTRUCTIONS SCREEN:

Using the Oculus Rift

Using the game controller

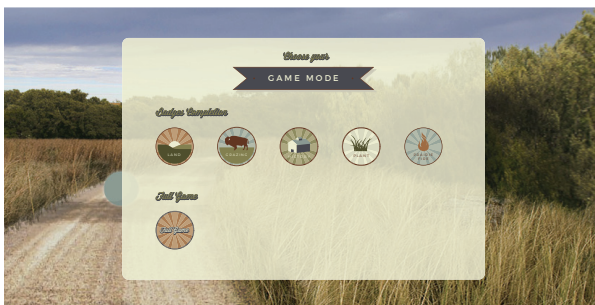


USER INTERFACE INSTRUCTIONS SCREEN:

Accessing the Map

Accessing the Backpack

Accessing the Control Center



GAME MODE SCREEN:

User chooses "Full Game" mode for access to all checkpoints; includes "Full Game" objective

User chooses "Badge" mode to focus on specific content; includes "Badge" objective

02 CHECKPOINT

BURNING: ECOLOGICAL MANAGEMENT

CONTENT:

V1.2 - Dominant tallgrass prairie grasses can be seen here, like Big Bluestem, Little Bluestem, Indian grass and switch grass.

B1.3 - Areas of the Konza Prairie are burned annually, or every 2, 4 or 20 years to maintain the grassland character.

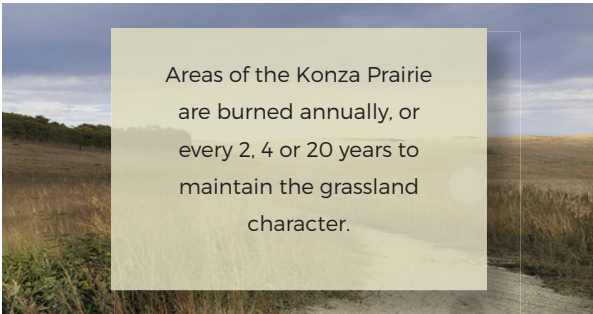
B2.1 - Prairie burning is an important eco-management tool, keeping woody plants and trees from taking over the grassland character of the prairie. Burning is part of the long-term ecological research here.

SCENE NOTES:

User approaches checkpoint and activates with trigger

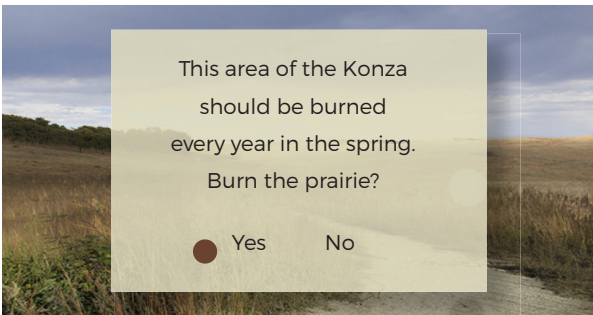
User focused on tallgrass prairie species, prairie burning intervals, and prairie burning as an eco-management tool





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



EVALUATION CONTENT SCREEN:

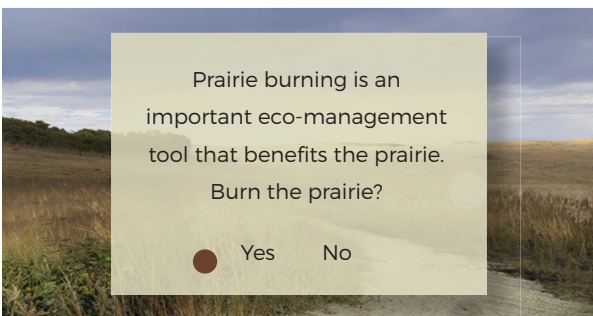
"This area of the Konza should be burned every year in the spring. Burn the prairie? (Y/N)"



CORRECT ANSWER: YES



User receives badge if season is set to spring; burning sequence video follows answer



INCORRECT ANSWER: NO

Content overlay reiterates prairie burning intervals, eco-management benefits, and important seasonal aspect; user prompted to check season preset

Evaluation content screen repeated

03 CHECKPOINT

DEWEY RANCH BARN

CONTENT:

C3.1 - The Dewey Cattle Company, who owned the Dewey Ranch Barn, surrounded the Hokanson Homestead in 1910.

C3.2 - Abandoned feed troughs suggest the area was used for cattle grazing, but is now an abandoned pasture.

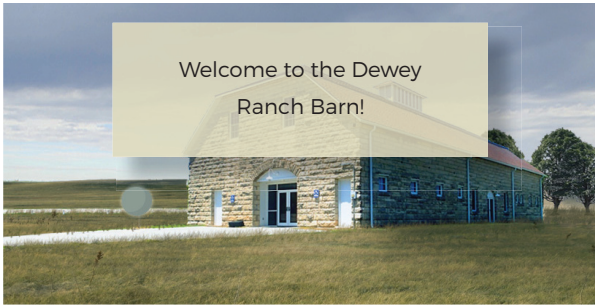
SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on the Dewey Ranch Barn

Historic View prompt





Welcome to the Dewey
Ranch Barn!

INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



Use the Historical View to see
a historical photo of the barn.



INTERACTIVE CONTENT SCREEN:



"Use the Historical View to see a
historical photo of the barn." Photo
stored in the Backpack



History badge collected



04 CHECKPOINT

WILDLIFE OBSERVATION

CONTENT:

C4.1 - Deer, turkey and birds heavily populate the Homestead Trail, and can be seen at the wildlife observation lean-to behind the barn

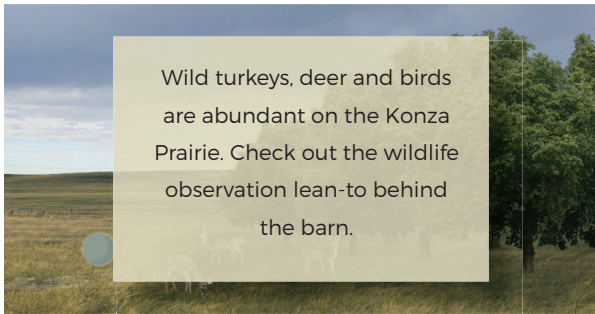
SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on the wildlife observation

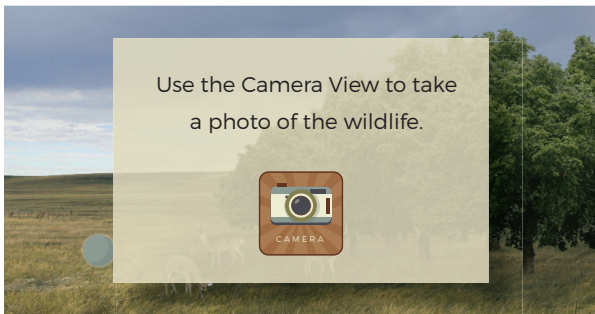
Camera View prompt





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN:



"Use the Camera View to take a photo of the wildlife you see"



History badge collected



CAMERA VIEW:

Simulates camera lens

User can focus content within lens



CAMERA VIEW:

Photo stored in the Backpack

05 CHECKPOINT

KINGS CREEK HYDROLOGY

CONTENT:

H1.1 - Kings Creek is one of two major streams

H1.2 - The area surrounding the creek is called a “riparian area.”

H3.1 - About 7% of the Konza Prairie is forested, and is concentrated around water sources like Kings Creek.

H3.2 - Cottonwoods and willow trees grow around water sources. Pioneers knew that if they found these trees, water was nearby.

S1.2 - Kings Creek’s far side of the bank is eroded away, showing the deep lowland soils.

SCENE NOTES:

User approaches checkpoint and activates with trigger

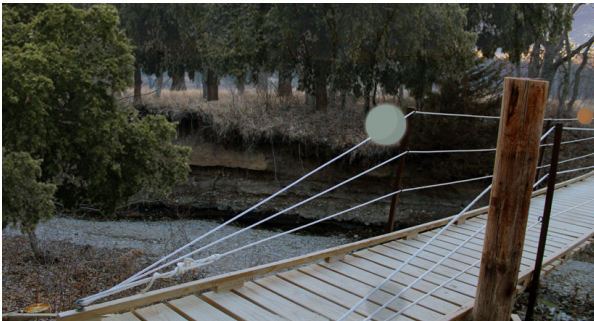
Focus on Kings Creek





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INFORMATIVE CONTENT SCREEN:

Highlight riparian area



INFORMATIVE CONTENT SCREEN:

Highlight deep lowland soils



INFORMATIVE CONTENT SCREEN:

Highlight cottonwoods and willow trees

06 CHECKPOINT

HOKANSON HOMESTEAD

CONTENT:

C2.1 - The Konza Prairie was originally a 95-acre Swedish-settled homestead from the 1870s, settled by the Hokanson brothers.

E3.1 - Limestone from these outcrops was used to build the original buildings on the Konza Prairie

C5.1 - Limestone was quarried from nearby limestone ledges to build these stone buildings.

SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on Hokanson Homestead

Historic View prompt





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN:



"Use the Historical View to see a historical photo of the house." Photo stored in the Backpack



History badge collected



07 CHECKPOINT

WEATHER ON THE KONZA PRAIRIE

CONTENT:

S2.1 - The limestone under the shallow soils came from an ancient ocean that covered the Konza Prairie about 250 million years ago.

H2.1 - Some areas of the Konza Prairie have been eroded by natural stream cutting. Most erosion happens slowly, but “flash floods” can alter a prairie stream dramatically.

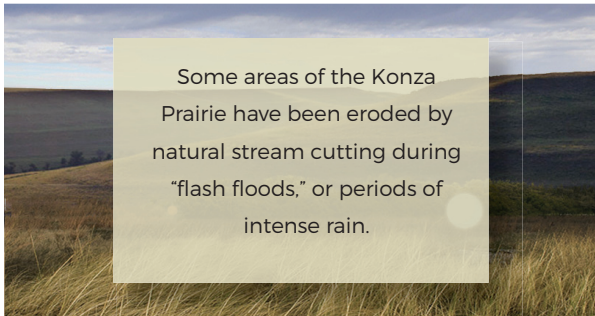
SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on water phenomena on the Konza Prairie

Weather preset prompts





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN: WEATHER

"Select different weather presets in the Control Center and observe the Konza Prairie under different weather conditions."



08 CHECKPOINT

SEASONS ON THE KONZA PRAIRIE

CONTENT:

V5.1 - About 600 species of prairie wildflowers bloom in the spring and summer on the Konza Prairie.

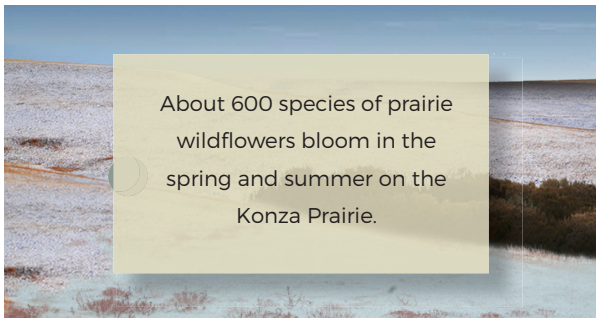
SCENE NOTES:

User approaches checkpoint and activates with trigger

Focuses on prairie wildflower species

Season preset prompts





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN:



"Select the spring season from the Control Center to see the wildflowers bloom."



Plant badge collected



09 CHECKPOINT

PRAIRIE FIRE: NATURAL PHENOMENA TO CONTROL BURNS

CONTENT:

B1.1 - Prairie fires used to be a naturally occurring phenomenon, but is now regulated by people to achieve the same outcome: ecological management of the prairie ecosystem.

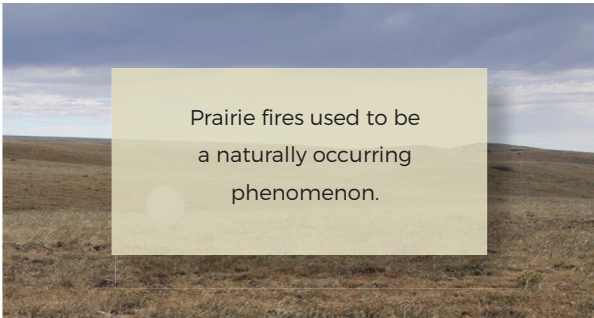
SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on fire as a natural phenomenon

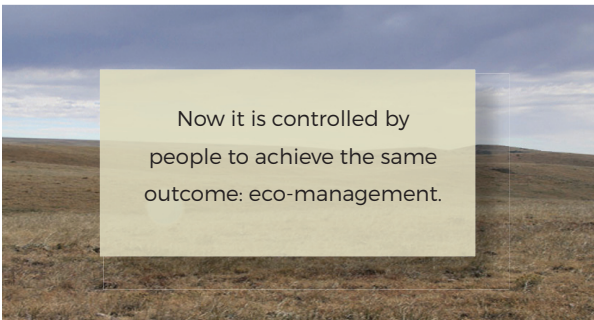
Prairie burning sequence video





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN: VIDEO

Prairie burning sequence video plays after informative content ends.



Prairie Fire badge collected



10 CHECKPOINT

LANDFORM AND SOIL FORMATION

CONTENT:

E1.1 - Water and wind have sculpted the landscape of the Konza Prairie as you can see from the ridgeline.

E2.2 - The landform with steep slopes on one side and gentle slopes on the other is called a "cuesta."

S1.1 - The soils on the Konza Prairie are made from weathered limestone dust from the Ice Age, and organic remains of plants.

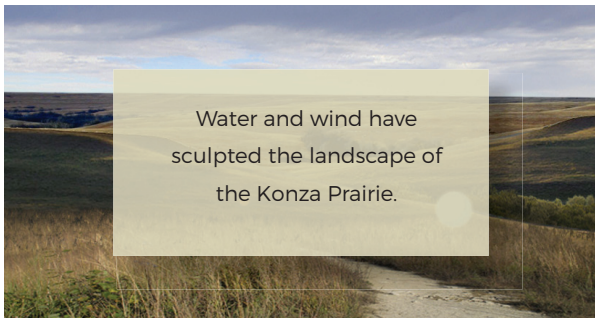
SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on landform and soil formation

Erosion sequence video

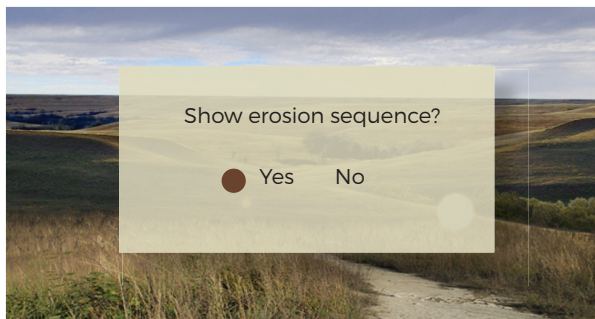




INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay

Water and wind have sculpted the landscape of the Konza Prairie. The soils on the Konza Prairie are made from weathered limestone dust from the Ice Age, and organic remains of plants.

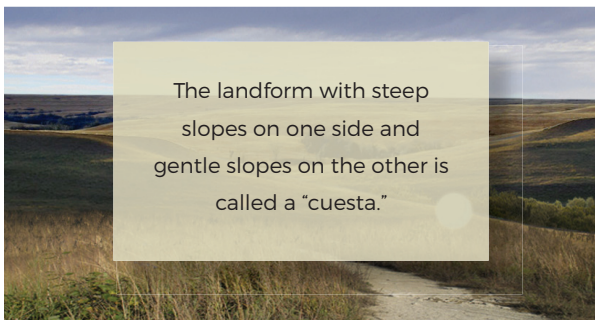


INTERACTIVE CONTENT SCREEN: VIDEO

"Show erosion sequence? (Y/N)" Land formation sequence to follow. If user chooses Yes, the badge is collected.



Landform badge collected



INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay

The landform with steep slopes on one side and gentle slopes on the other is called a "cuesta."



EVALUATION CONTENT SCREEN:

"Which landform is a cuesta?"

User selects from three highlighted landforms. If correct, the badge is collected.



Landform badge collected

11 CHECKPOINT

SHORTGRASS PRAIRIE

CONTENT:

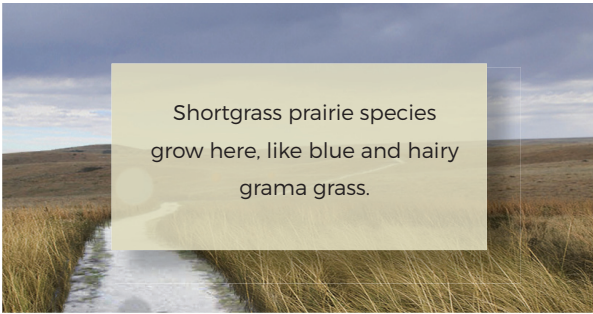
V3.1 - Shortgrass prairie species grow here, like blue and hairy grama grasses

SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on shortgrass prairie species





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN:

"Collect the highlighted shortgrass prairie plant samples." If plant samples are collected, the plant badge is collected.



INTERACTIVE CONTENT SCREEN:

User approaches highlighted plant samples, collects the sample using controller button, and supplemental information is included in informative text overlay with plant sample photograph.



INTERACTIVE CONTENT SCREEN:

If plant samples are collected, the plant badge is collected.



Plant badge collected

12 CHECKPOINT

NATIVE AMERICANS AND THE BISON

CONTENT:

T3.1 - This trail is usually open to researchers only. You might see bison along this trail.

G1.1 - Native Americans hunted the bison and used almost every part of the animal for food, tools and clothing.

SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on trail and intro to bison

Historical View prompt





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN: VIEWS



"Use the Historical View to see a historical photo of the Native Americans."



Grazing badge collected



13 CHECKPOINT

BISON GRAZING: ECOLOGICAL MANAGEMENT

CONTENT:

G1.2 - Millions of bison once roamed and grazed on the Great Plains, but were almost driven to extinction by the pioneers in the 1880s.

G2.1 - There are about 300 bison here that are part of the long-term ecological research program for the Konza Prairie.

SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on bison

Historical View prompt





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN: VIEWS



"Use the Historical View to see a historical photo of the bison."



Grazing badge collected



14 CHECKPOINT

BISON GRAZING: ECOLOGICAL MANAGEMENT

CONTENT:

G3.1 - Grazing is an important ecological process for the prairie, maintaining the grassland character of the Konza Prairie

G3.2 - Bison can remove about 54% of yearly plant production on the prairie. Since they primarily eat tallgrass plant species, plant diversity and flowering plant species are typically higher in bison pastures compared to cattle pastures.

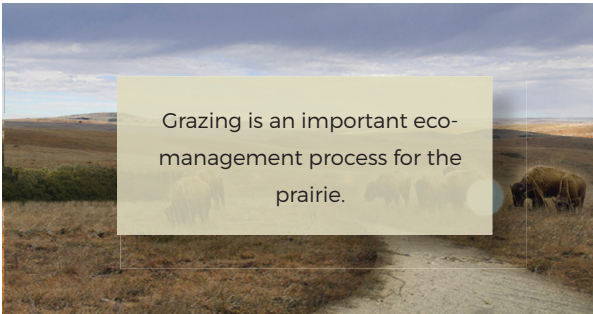
SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on bison grazing as ecological management

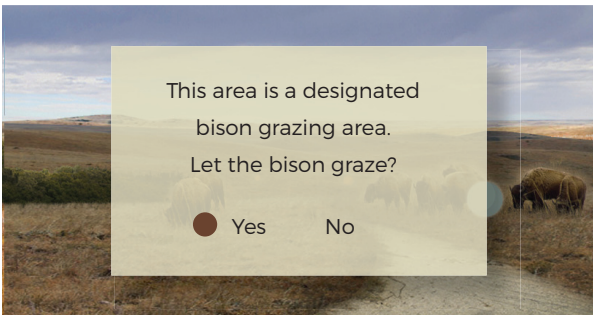
Bison grazing sequence video





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



EVALUATION CONTENT SCREEN:

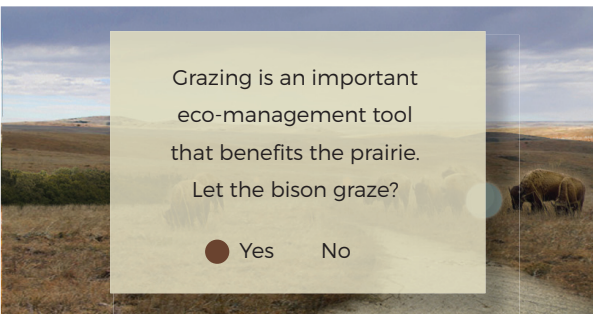
"This area is a designated bison grazing area. Let the bison graze? (Y/N)"



CORRECT ANSWER: YES



User receives badge if they recognize that the bison are a positive force on the prairie and that they're currently in a grazing area: grazing sequence video follows answer



INCORRECT ANSWER: NO

Content overlay reiterates bison grazing location, eco-management benefits, and grazing impacts on the prairie vegetation; user prompted to check season preset

Evaluation content screen repeated

15 CHECKPOINT

TALLGRASS PRAIRIE

CONTENT:

B3.1 - The Konza Prairie is dominated by fire-tolerant grasses

V1.2 - Dominant tallgrass prairie grasses can be seen here, like Big Bluestem, Indian grass, Switch grass and Little Bluestem

V4.1 - Grasses on the Konza Prairie survive drought conditions with their extensive root systems

V4.2 - Big Bluestem can have root systems up to 12 feet long

SCENE NOTES:

User approaches checkpoint and activates with trigger

Focus on tallgrass prairie species and root systems





INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



INTERACTIVE CONTENT SCREEN:

"Collect the highlighted tallgrass prairie plant samples. Take a look at the root systems!"



INTERACTIVE CONTENT SCREEN:

User approaches highlighted plant samples, collects the sample using controller button, and supplemental information is included in informative text overlay with plant sample photograph.



INTERACTIVE CONTENT SCREEN:

If plant samples are collected, the plant badge is collected.



Plant badge collected

16 CHECKPOINT

PRAIRIE SUCCESSION

CONTENT:

B1.3 - Areas of the prairie are burned annually, or every 2, 4 or 20 years

B2.2 - There is a significant difference the prairie succession of areas burned every year and every 4 years, as you can see here.

NOTES:

User approaches checkpoint and activates with trigger

Focus on prairie succession

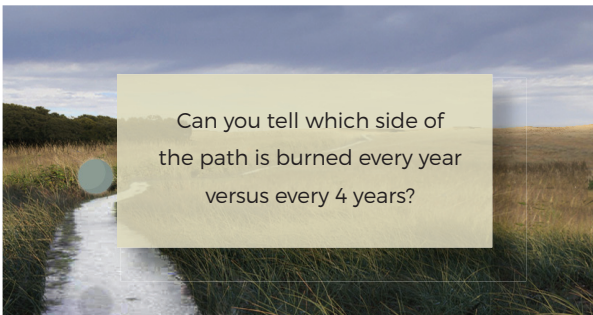




Areas of the prairie are burned annually, or every 2, 4 or 20 years.

INFORMATIVE CONTENT SCREEN:

Checkpoint triggers content overlay



Can you tell which side of the path is burned every year versus every 4 years?

EVALUATION CONTENT SCREEN:

“There are more woody plant species in prairie areas that are burned less often. Can you tell which side of the path is burned every 4 years versus every year?”



Every Year ● Every 4 Years

INTERACTIVE CONTENT SCREEN:

User must label which side of the prairie is burned every year and which side is burned every 4 years.

Correct Answers:

Left side: Every 4 years Right side: Every year



● Every Year ● Every 4 Years

INTERACTIVE CONTENT SCREEN:

If the labels are correct, the prairie burning badge is collected.



Prairie Fire badge collected

17 CHECKPOINT

EXIT SEQUENCE

SCENE NOTES:

Exit sequence

Backpack review of badges and photos

Evaluation content: Modified Environmental Awareness Scale





INFORMATIVE CONTENT SCREEN:

User has completed the checkpoints
Backpack review for content reiteration



EVALUATION CONTENT SCREEN:

Evaluation content reiterated through collected badge review
Collected photo review



EVALUATION CONTENT SCREEN:

Evaluation questions: Modified Environmental Awareness Scale (Likert-scale)
User adjusts scale using game controller



FINAL CONTENT SCREEN:

Scene fades into introduction screen for next user to begin game



TECHNOLOGY EXPLORATION

DESCRIPTION OF TECHNOLOGY EXPLORATION & PROGRAM CAPABILITY

A technology exploration was conducted to explore the capabilities and compatibilities of four programs: ArcGIS, SketchUp, Vue, and Unity. Each of these programs could contribute to the final visualization creation, but the program capabilities and compatibilities needed to be explored first to understand the optimal workflow.



SOFTWARE

ArcGIS (ESRI, 2014) is a geographic information system for working with maps and geographic information. Spatial datasets were collected from the Konza Prairie Biological Station website and organized into base maps using ArcGIS. These basemaps provided foundational information for checkpoint information, checkpoint location and proposed virtual trail location.

SketchUp (Trimble, 2014) is a 3D modeling program with a simple user interface, helpful user support, a large public marketplace for components, and a shallow learning curve. Terrain and vegetation components were explored for graphic quality and compatibility between programs.

Vue (E-on Software, 2014) is an advanced computer graphics (CG) program that allows the designer to create realistic digital environments. The program has a high learning curve, complicated user interface, minimal free user support, and a component library available for purchase (Cornucopia3D). Vue was used in the program compatibility study to import components from SketchUp, and export components to Unity. Preliminary terrain modeling was also explored using heightmap data from ArcGIS.

Unity (Unity Technologies 2014) is an industry leading development program for creating multiplatform 2D and 3D games and interactive experiences. The program has a somewhat complicated user interface and learning curve, helpful user support, and an asset (component) store available for purchase (Unity Asset Store). Unity was used

in the program compatibility study to import assets, as well as create assets within the Unity interface alone. Parameters and user interactivity assets can be assigned to assets to create the gaming experience.

PORTABLE DEVICES

Oculus Rift is a head-mounted display technology whose software includes a plug-in to Unity Pro for an immersive gaming experience. Oculus Rift would be used as the display technology to view the final 3D learning environment.

PROGRAM COMPATIBILITY TESTING

In order to create the Konza Prairie 3D learning environment, terrain and vegetation components were tested for program compatibility. This preliminary test offered insight into the optimal workflow between programs, and assess program compatibility.

The first compatibility test was conducted between SketchUp and Vue with terrain and vegetation components. Each component was created in SketchUp, exported, and imported into Vue. Component description, file type, file size and resolution, and notes are documented in Figure 7.1. The results of this test show little compatibility between SketchUp and Vue relative to vegetation representation. Components retained basic shape, but did not retain small details such as leaves, transparency, and texture consistency.

The second compatibility test was conducted between Vue and Unity. Similar to the SketchUp and Vue compatibility test, the components were created in Vue, exported and imported as assets in Unity. Component description, file type, file size and resolution, and notes are documented in Figure 7.2. The results of this test show little compatibility between Vue and Unity. Components retained basic shapes, but did not retain small details such as leaves, transparency, and texture consistency. The final results of the Vue-Unity test were more consistent than the SketchUp-Vue tests, but neither was acceptable to be used in the Konza Prairie 3D learning environment.

Object	Polygons & File Size	Texture Map Resolution	Export Program	Export File Type	Import Program
Terrain	132,098 Polygons/ 2.64 MB	1200 x 1200	Vue	3DS File (*.3ds)	Unity
Terrain	132,098 Polygons/ 2.64 MB	1200 x 1200	Vue	OBJ File (*.obj)	Unity
Terrain	209,952 Polygons/ 13.85 MB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Terrain	209,952 Polygons/ 13.85 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity
Fir Tree	112,050 Polygons/ 7.39 MB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Fir Tree	112,050 Polygons/ 7.39 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity
Maple Tree	679,050 Polygons/ 13.56 MB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Maple Tree	679,050 Polygons/ 13.56 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity
Grass	107,550 Polygons/ 2.15 MB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Grass	107,550 Polygons/ 7.10 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity
Road (no terrain)	37,832 Polygons/ 815.04 kB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Road (no terrain)	37,832 Polygons/ 2.63 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity

FIGURE 7.1: Program Compatibility Table: SketchUp and Vue

Object Import Observations	Notes
Terrain imported with basic green color; texture and material can be set in side bar after copying image files to materials folder; mesh is selected through individual mesh parts	Vue generated terrain; grass material applied; Unity warning "Meshes may not have more than 'x' vertices at the moment;" split into two terrain mesh parts; zooming into *.3ds files cuts part of mesh out of view
Terrain imported with basic green color; material copied as *.mtl file to materials folder in Unity, but is not a supported filetype to apply to mesh; other material files can be applied to mesh; mesh is selected through individual mesh parts	Vue generated terrain; grass material applied; Unity warning "Meshes may not have more than 'x' vertices at the moment;" split into two terrain mesh parts; materials and textures can be dragged onto terrain
Terrain imported with basic green color; texture and material can be set in side bar after copying image files to materials folder; mesh is selected through individual mesh parts	Vue generated terrain; grass material applied; Unity warning "Meshes may not have more than 'x' vertices at the moment;" split into three terrain mesh parts; zooming into *.3ds files cuts part of mesh out of view
Terrain imported with basic green color; material copied as *.mtl file to materials folder in Unity, but is not a supported filetype to apply to mesh; other material files can be applied to mesh; mesh is selected through individual mesh parts	Vue generated terrain; grass material applied; Unity warning "Meshes may not have more than 'x' vertices at the moment;" split into two terrain mesh parts; materials and textures can be dragged onto terrain
Tree imported with basic shape; copied image files to materials folder and applied to mesh; mesh transparency did not work	Tree from Vue plant library (free); Unity warning said could not open *.3ds file format but still imported; try editing image files for transparency effect
Tree imported with twisted planes for branches and foliage; used *.3ds image files for textures (*.mtl file not supported); mesh transparency did not work	Tree from Vue plant library (free); try editing image files for transparency effect
Tree imported with basic shape; copied image files to materials folder and applied to mesh; mesh transparency did not work	Tree from Vue plant library (free); Unity warning said could not open *.3ds file format but still imported; try editing image files for transparency effect
Tree imported with twisted planes for branches and foliage; used *.3ds image files for textures (*.mtl file not supported); mesh transparency did not work	Tree from Vue plant library (free); try editing image files for transparency effect
Polygons imported but shape was not accurate; basic green color automatically imported; copied image files to materials and applied to polygons; did not look like original file	Grass from Vue plant library (free)
Polygons imported but shape was not accurate; basic green color automatically imported; copied image files to materials and applied to polygons; did not look like original file	Grass from Vue plant library (free)
Road imported correctly; materials copied to materials folder and applied	Road spline on Vue-generated terrain
Road imported correctly; materials copied to materials folder and applied	Road spline on Vue-generated terrain

Object	Polygons & File Size	Texture Map Resolution	Export Program	Export File Type	Import Program
Terrain	132,098 Polygons/ 2.64 MB	1200 x 1200	Vue	3DS File (*.3ds)	Unity
Terrain	132,098 Polygons/ 2.64 MB	1200 x 1200	Vue	OBJ File (*.obj)	Unity
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Fir Tree	112,050 Polygons/ 7.39 MB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Fir Tree	112,050 Polygons/ 7.39 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity
Maple Tree	679,050 Polygons/ 13.56 MB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Maple Tree	679,050 Polygons/ 13.56 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity
Grass	107,550 Polygons/ 2.15 MB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Grass	107,550 Polygons/ 7.10 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity
Road (no terrain)	37,832 Polygons/ 815.04 kB	2000 x 2000	Vue	3DS File (*.3ds)	Unity
Road (no terrain)	37,832 Polygons/ 2.63 MB	2000 x 2000	Vue	OBJ File (*.obj)	Unity

FIGURE 7.2: Program Compatibility Table: Vue and Unity

Object Import Observations	Notes
Terrain imported with basic green color; texture and material can be set in side bar after copying image files to materials folder; mesh is selected through individual mesh parts	Vue generated terrain; grass material applied; Unity warning "Meshes may not have more than 'x' vertices at the moment;" split into two terrain mesh parts; zooming into *.3ds files cuts part of mesh out of view
Terrain imported with basic green color; material copied as *.mtl file to materials folder in Unity, but is not a supported filetype to apply to mesh; other material files can be applied to mesh; mesh is selected through individual mesh parts	Vue generated terrain; grass material applied; Unity warning "Meshes may not have more than 'x' vertices at the moment;" split into two terrain mesh parts; materials and textures can be dragged onto terrain
Terrain imported with basic green color; texture and material can be set in side bar after copying image files to materials folder; mesh is selected through individual mesh parts	Vue generated terrain; grass material applied; Unity warning "Meshes may not have more than 'x' vertices at the moment;" split into three terrain mesh parts; zooming into *.3ds files cuts part of mesh out of view
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Tree imported with twisted planes for branches and foliage; used *.3ds image files for textures (*.mtl file not supported); mesh transparency did not work	Tree from Vue plant library (free); try editing image files for transparency effect
Polygons imported but shape was not accurate; basic green color automatically imported; copied image files to materials and applied to polygons; did not look like original file	Grass from Vue plant library (free)
Polygons imported but shape was not accurate; basic green color automatically imported; copied image files to materials and applied to polygons; did not look like original file	Grass from Vue plant library (free)
Road imported correctly; materials copied to materials folder and applied	Road spline on Vue-generated terrain
Road imported correctly; materials copied to materials folder and applied	Road spline on Vue-generated terrain

VEGETATION EDITOR

The graphic quality of vegetation is an essential component of the 3D learning environment. Trees and grasses were tested in the program compatibility test for asset accuracy and transfer between programs, but the end product was not graphically acceptable. While SketchUp, Vue and Unity all provide high quality vegetation components and assets, and editing of these components, transferring the quality between programs was not successful.

Since Unity is the last program in the workflow capable of adding vegetation assets, editing of these assets was further explored. Unity provides a standard tree that can be edited using the “tree creator,” and can be altered into any type of tree necessary. This process is similar for grasses, which can be “painted” onto the terrain in various patterns and densities. A visual explanation of the “tree creator” is illustrated in Figure 7.3.

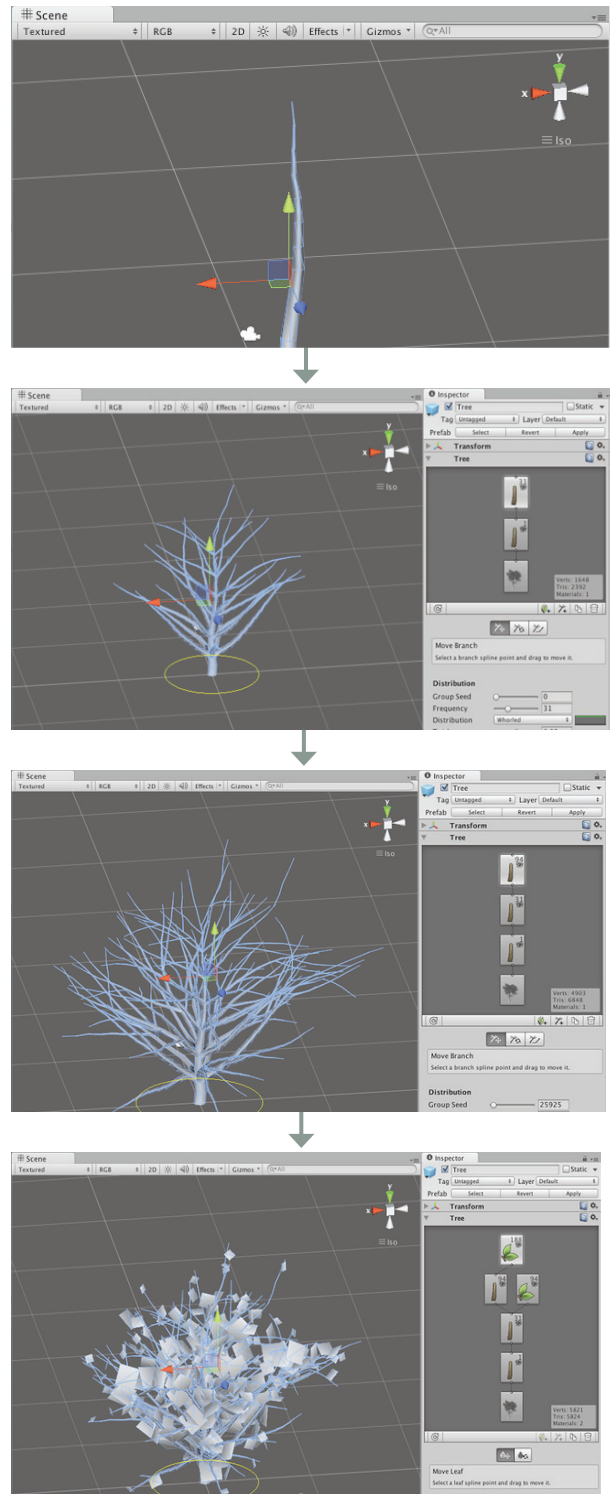
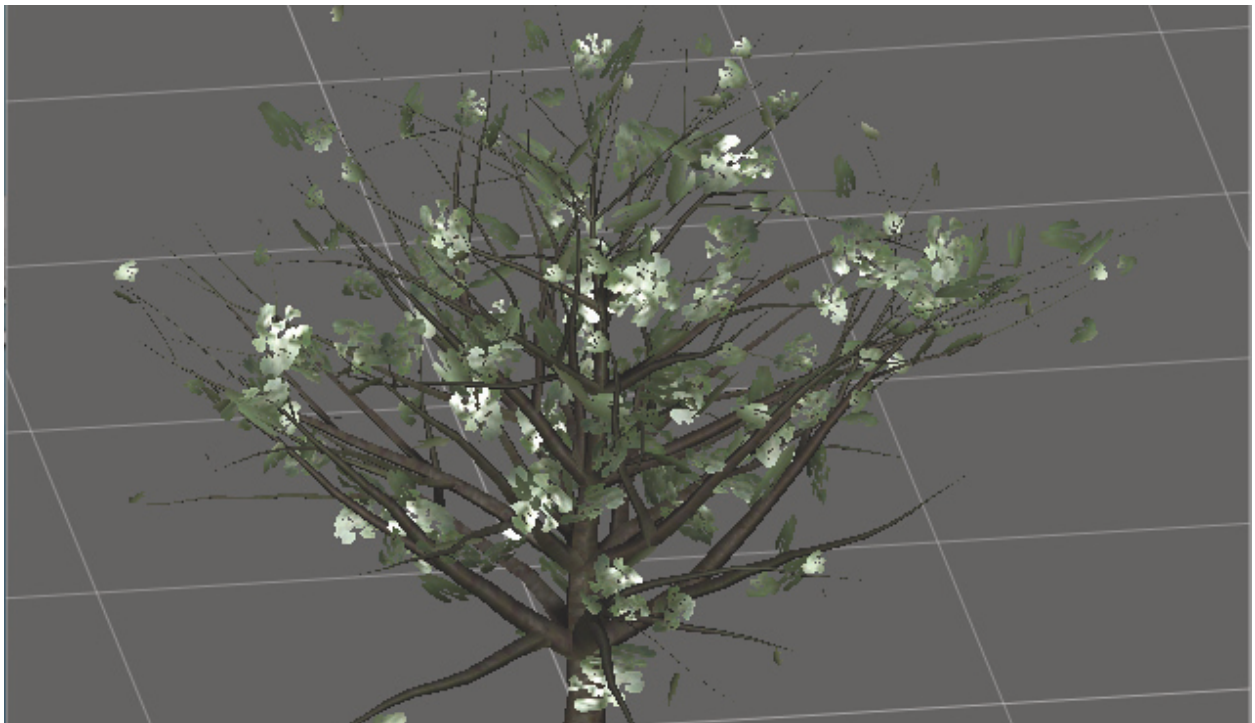
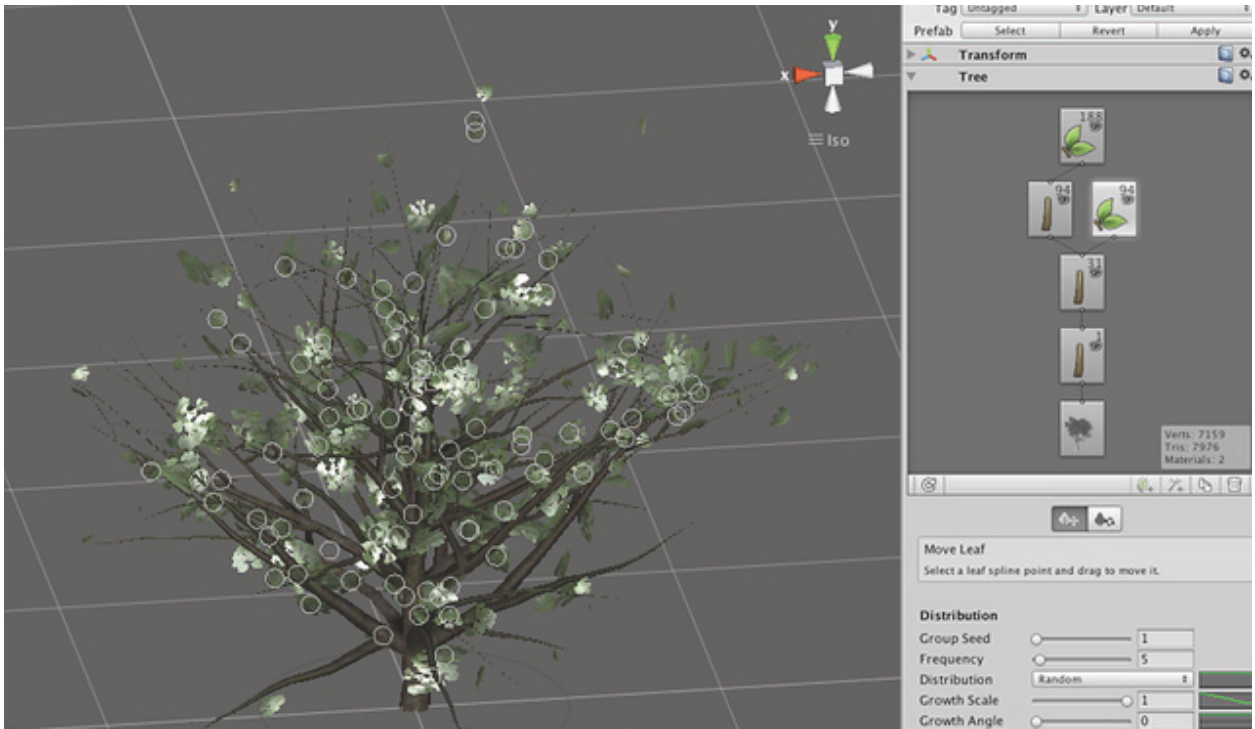


FIGURE 7.3: (right) Tree Creator Visual Instructions

Source: “Building Your First Tree,” Unity Documentation
<http://docs.unity3d.com/Manual/tree-FirstTree.html>



PROGRAM COMPATIBILITY FINDINGS

The program compatibility test was revealing of how the programs SketchUp, Vue and Unity interact in reference to vegetation representation and terrain modeling. From the testing, it can be concluded that 3DS files (*.3ds) and OBJ files (*.obj) were the most compatible filetypes between SketchUp, Vue and Unity. OBJ files were my personal preference, since they had fewer importing problems, and zooming in and out did not cut out parts of the model like *.3ds files.

Unity is capable of creating terrain, adding and editing roads and vegetation, and programming parameters for the user to experience the environment, thus making Vue unnecessary in the workflow. While Vue is a valuable program for creating virtual environments, it's recommended that Unity be used for the 3D learning environment creation.

Vue and Unity are typically used independently, so each program provides the necessary assets to be self-sufficient. SketchUp can also be used independently, but is compatible with a variety of other software programs that were not explored in the program compatibility testing.

TECHNOLOGY RECOMMENDATIONS:

After understanding the program capabilities and compatibilities, technology recommendations for the final visualization were made. Based on the compatibility tests and explorations, it is recommended that the final prototype be built using Unity for program consistency. Unity has complex terrain and vegetation modeling capabilities, atmosphere and environment customization abilities, and user interactivity options. Unity also has the Oculus Rift plug-in for ease of use, which requires little effort for the designer to program the display technology.

The trail system in the visualization should be a series of wayfinding points. The points will be created with Unity colliders, which define the shape of an object for the purposes of physical collisions (Unity Manual). This means that when the user passes through a wayfinding point, another point is triggered to appear along the proposed path to guide the user through the 3D learning environment. Colliders should also be used when designing the checkpoint system. The checkpoint objects should look different than the wayfinding points, but act similar. The checkpoints colliders are activated when the user is in close proximity to the object.

Due to the large quantity of vegetation in the 3D learning environment, procedural vegetation is most likely necessary for quick, real-time rendering as the user moves through the environment. It is not necessary to render vegetation assets that are not immediately viewed by the user in the environment, which saves rendering time. Vegetation assets should

be downloaded from the Unity Asset Store and edited as necessary in the asset editor.

A fly-in entry sequence is possible by creating two different scenes: the first with minimal vegetation detail since the user is farther away, and the second with more refined vegetation detail as the user approaches ground-level. A cloud break should be used as a transition between the two scenes.



EVALUATING ENVIRONMENTAL LEARNING

While creating simple visualizations is not difficult, very few have been produced to scientific standards. Even fewer have produced published scientific results about the responses. However, this lack of formally published work should not neglect the unpublished responses and effectiveness of visualizations (Sheppard, 2005). Evaluating and publishing scientific results of visualization responses should become an essential component of visualizations to support and substantiate environmental education benefits for future use.



EVALUATION LOGIC MODEL

Evaluation of the Konza Prairie 3D learning environment is outlined in the evaluation logic model (see Figure 8.1), focusing on three main learning objectives:

- **Learning Objective 1:** The user will increase environmental awareness on a researcher developed Likert-scale similar to the Environmental Attitudes Scale, New Ecological Paradigm Scale for Children (NEP-C), or Children’s Environmental Attitudes & Social Knowledge Scale (CHEAKS).
- **Learning Objective 2:** Users will have a better understanding of ecological management practices in prairie grasslands.
- **Learning Objective 3:** Users will understand the basic characteristics of the Konza Prairie and other similar grassland ecosystems.

This evaluation model focuses on cognitive, affective and behavioral responses (knowledge, attitudes and behavior) previously outlined by Sheppard (2005) in the “Theoretical Effects of Different Types of Landscape Visualization in Stimulating Perceptions and Behavior in Response to Climate Change.”

Comprehension signs (short-term impacts) are presented in the checkpoints through interactive components and questions. Figure 8.3 illustrates Checkpoint 02 and how evaluation content may be included in the checkpoint sequences.

FIGURE 8.1: (right) Evaluation Logic Model

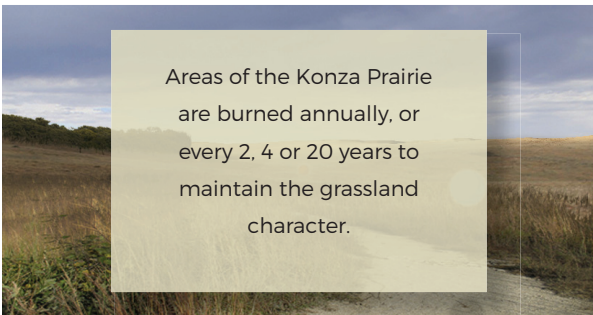
Source: Created by Natalie Webb

Learning Objective	Users will increase environmental awareness on Modified Environmental Awareness Scale, or similar researcher developed scale.	Users will have a better understanding of ecological management practices in prairie grasslands.	Users will understand the basic characteristics of the Konza Prairie and other similar grassland ecosystems
Comprehensive Signs (short-term impacts)	Users are immediately aware of human impact on the Konza Prairie.	Users are immediately aware of ecological management practices in prairie grasslands and why they're used, demonstrating knowledge of skills to take action on environmental issues.	Users are immediately aware of the characteristics of the Konza Prairie and other similar ecosystems
Value Judgement (intermediate impacts)	Individuals are more sympathetic towards their immediate environment and knowledgeable of human impact on ecological management processes.	Individuals become supportive of ecological management practices in their local environments, understanding their role in environmental issues.	Individuals have an appreciation for the character and complexity of prairie-grassland ecosystems
Action & Advocacy (long-term impacts)	Population is more environmentally aware of their impacts on the environment and sensitive to preserving the environment through ecological management.	Population accepts ecological management practices as a necessary part of maintaining the world's ecosystems and climate-change mitigation, some users may become involved in eco-management.	Population seeks to preserve prairie-grassland ecosystems
Evaluation	Increase on researcher developed Likert-scale after game completion; change in environmental awareness.	Increase knowledge of ecological management practices in prairie grasslands as climate-change mitigation after game completion.	Increase knowledge of Konza Prairie grassland characteristics and ecosystems after game completion
Measurement Plan	Use Modified Environmental Awareness Scale, or similar researcher developed Likert-scale at completion of game.	Evaluation questions at checkpoints and at the end of game about ecological management practices used on the Konza Prairie.	Evaluation questions at checkpoints and at end of game about characteristics of the Konza Prairie and other similar grassland ecosystems
Included in Checkpoints:	Checkpoint 17	Checkpoints 02, 09, 12, 13, 14, 16,	Checkpoints 01, 02, 04, 05, 06, 07, 08, 10, 11, 15,



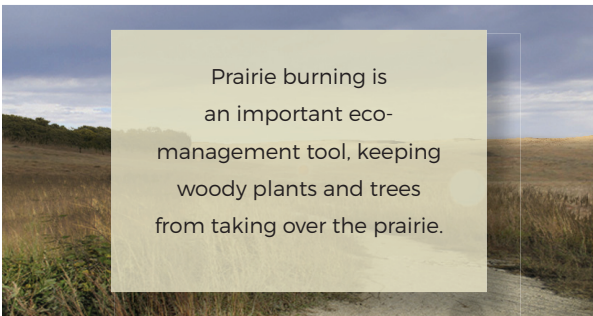
02 CHECKPOINT INTRODUCTION:

User approaches checkpoint and activates with trigger



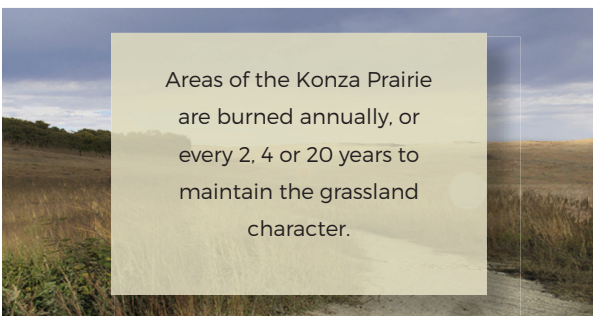
INFORMATIVE CONTENT SCREEN:

"Areas of the Konza Prairie are burned annually, or every 2, 4, or 20 years to maintain the grassland character."



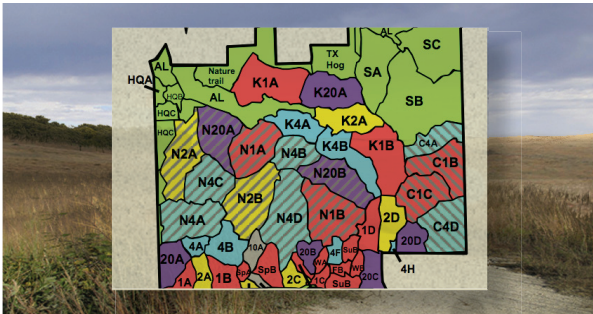
INFORMATIVE CONTENT SCREEN:

"Prairie burning is an important eco-management tool, keeping woody plants and trees from taking over the grassland character of the prairie. Burning is part of the long-term ecological research here."



INTERACTIVE CONTENT SCREEN:

"Here are the different prairie burning zones. Click on the different burning intervals to see which zones are affected, and see what each prairie looks like before it's burned."



INTERACTIVE CONTENT SCREEN:

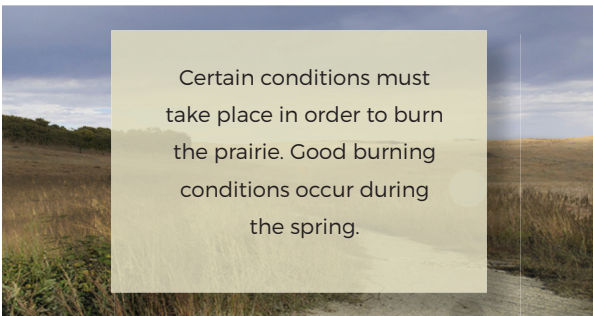
Interactive pop-up map with burn zones and burn intervals

User selects burn interval to see where the zones are located



INTERACTIVE CONTENT SCREEN:

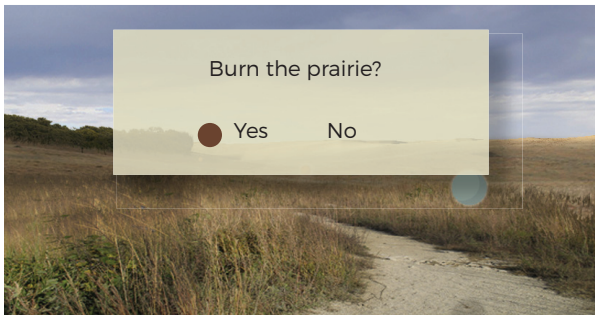
Video simulation of prairie before, during and after burning





INTERACTIVE CONTENT SCREEN:

User adjusts wind, season and humidity sliders
 Burn Conditions Screen enlarged in Figure 8.2



EVALUATION CONTENT SCREEN:

"Burn the prairie? (Y/N)"



CORRECT CONDITIONS:



User receives badge if season is set to spring, wind conditions set to 5-15 mph, and relative humidity is 40-70%.

Burning sequence video follows answer



INCORRECT CONDITIONS:

Screen fills with smoke, fire out of control

Prairie Fire badge is not earned

User prompted to retry conditions, maximum two tries before conditions are automatically set to good burning conditions and video plays



FIGURE 8.2: Burn Conditions User Interface

Source: Created by Natalie Webb

FIGURE 8.3: Checkpoint Evaluation Storyboard

Source: Created by Natalie Webb

EVALUATING LEARNING OBJECTIVES

Evaluating user environmental awareness (Learning Objective 1) should be measured using a researcher developed Likert-scale at the end of the game. This scale should be similar to the Environmental Attitudes Scale, New Ecological Paradigm Scale for Children (NEP-C), or the Children's Environmental Attitudes & Social Knowledge Scale (CHEAKS), but modified for both the target audience (middle and high school students) and visualization content. By the end of the game, users will have completed the checkpoint sequence, presented with a series of questions, and asked to select an answer based on a 5-point scale.

Evaluating the user's knowledge about ecological management practices in prairie grasslands (Learning Objective 2) will be tested during the game and at the end "backpack overview" sequence. Checkpoints with ecological management content contain interactive sequences and prompts with visual content (see Figure 8.3).

A second evaluation takes place at the end of the game, when the backpack overview sequence is occurring. During the backpack overview, the user reviews the collected items within their backpack with some additional information presented. The user is prompted to answer questions about the importance of each item as it responds to the learning objective.

Evaluating the user's basic understanding of prairie grassland ecosystem characteristics (Learning Objective 3) will be evaluated similar to Learning Objective 2. Checkpoints with information pertaining to learning objective 3

may contain a variety of evaluation prompts, sequences and written information, illustrating the characteristics of the Konza Prairie to the user. Evaluation prompts may be given to test the user's understanding after information is given, and evaluation points awarded based on the answers. Like the backpack overview evaluation used in learning objective 3, the user reviews collected items within their backpack with additional information presented. The user is prompted to answer questions about the importance of each item as it responds to the learning objective.

EVALUATION AND NEXT GENERATION SCIENCE STANDARDS

Evaluation content and questions should draw connections to the Next Generation Science Standards (The 2013 Kansas College and Career Ready Standards for Science; KCCRSS). According to the Next Generation Science Standards Influence of Engineering, Technology, and Science on Society and the Natural World, crosscutting core ideas in natural sciences and how these ideas are supported in technological advances has produced a series of connection statements. In grades 6-8 (middle school), these connection statements include (NGSS, 2013):

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.
- The use of technologies are driven by people's needs, desires and values;

by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

- Technology use varies over time and from region to region.
- In grades 9-12 (high school), these connection statements include (NGSS, 2013):
- Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction and communications.
- Engineers continuously modify these systems to increase benefits while decreasing costs and risks.
- New technologies can have deep impacts on society and the environment, including some that were not anticipated.
- Analysis of costs and benefits is a critical aspect of decisions about technology.

These connection statements focus heavily on science, engineering and technology, which directly relates to visualization technologies in environmental education. As stated in the Next Generation Science Standards Appendix J (see Appendix A), "The continued growth of the world's population along with technological advances and scientific discoveries will continue to impact the lives of our students... they will be asked to make decisions that influence the development of technologies and the direction of scientific research...it is important for teachers to engage their students in learning

about the complex interactions among science, technology, society and the environment" (pg 6, 2013). Next Generation Science Standards for the Konza Prairie 3D learning environment should be focused in, but not limited to:

- **Middle School Weather & Climate:** Disciplinary core ideas of weather and climate (ESS2.D) and global climate change (ESS3.D) where students should: ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century (MS-ESS3-5).
- **High School Weather & Climate:** Disciplinary core ideas of weather and climate (ESS2.D) and global climate change (ESS3.D) where students should: use a model to describe how variations in the flow of energy into and out of Earth's systems result in climate change (HS-ESS2-4); and analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems (HS-ESS3-5).
- **High School Human Sustainability:** Disciplinary core ideas of weather and climate (ESS2.D), natural resources (ESS3.A), natural hazards (ESS3.B), human impacts on earth systems (ESS3.C), and global climate change (ESS3.D) where students should: construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity (HS-ESS3-1); create computational simulation

to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity (HS-ESS3-3); evaluate or refine a technological solution that reduces impacts of human activities on natural systems (HS-ESS3-4); use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity (HS-ESS3-6).

- **High School Interdependent Relationships in Ecosystems:** Disciplinary core ideas of ecosystem dynamics, functioning and resilience (LS2.C) and biodiversity and humans (LS4.D) where students should: evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem (HS-LS2-6); design, evaluate and refine a solution for reducing the impacts of human activities on the environment and biodiversity (HS-LS2-7); and create or revise a simulation to test a solution to mitigate adverse impacts of human activity on biodiversity (HS-LS4-6).
- **Common Core State Standard Connections** may include, but are not limited to: SL.8.5 include multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points (MS-ESS2-6).

EXPLORING VALUE JUDGMENT

User value judgment presents itself in the support or opposition of the ecological management aspects of the Konza Prairie. The information presented in the Konza Prairie 3D learning environment is ongoing research, which means it has the potential to shift despite the years of research already put into the topics. Opposition to some research already exists pertaining to the involvement of people in prairie burning, air quality during burning periods, and specific prairie burning seasons (Carpenter, 2014). Kansas State University and The Nature Conservancy are supportive of the ecological management practices that occur on the Konza Prairie, focusing their long-term ecological research on these management practices.

Information to evaluate the value judgment (intermediate impacts) of the Konza Prairie 3D learning environment users could be collected over years through local newspaper articles, research, and public opinion in areas directly and indirectly affected by the Konza Prairie ecological management practices.

EVALUATING ACTION & ADVOCACY

Action and advocacy (long-term impacts) for the ecological management practices used on the Konza Prairie are focused in a variety of organizations and facilities, ranging in size. Some of these organizations include: Friends of the Konza Prairie, Flint Hills Discovery

Center, Kansas State University, The Nature Conservancy, Konza Prairie Biological Station, Sierra Club Kansas Chapter, and many others.

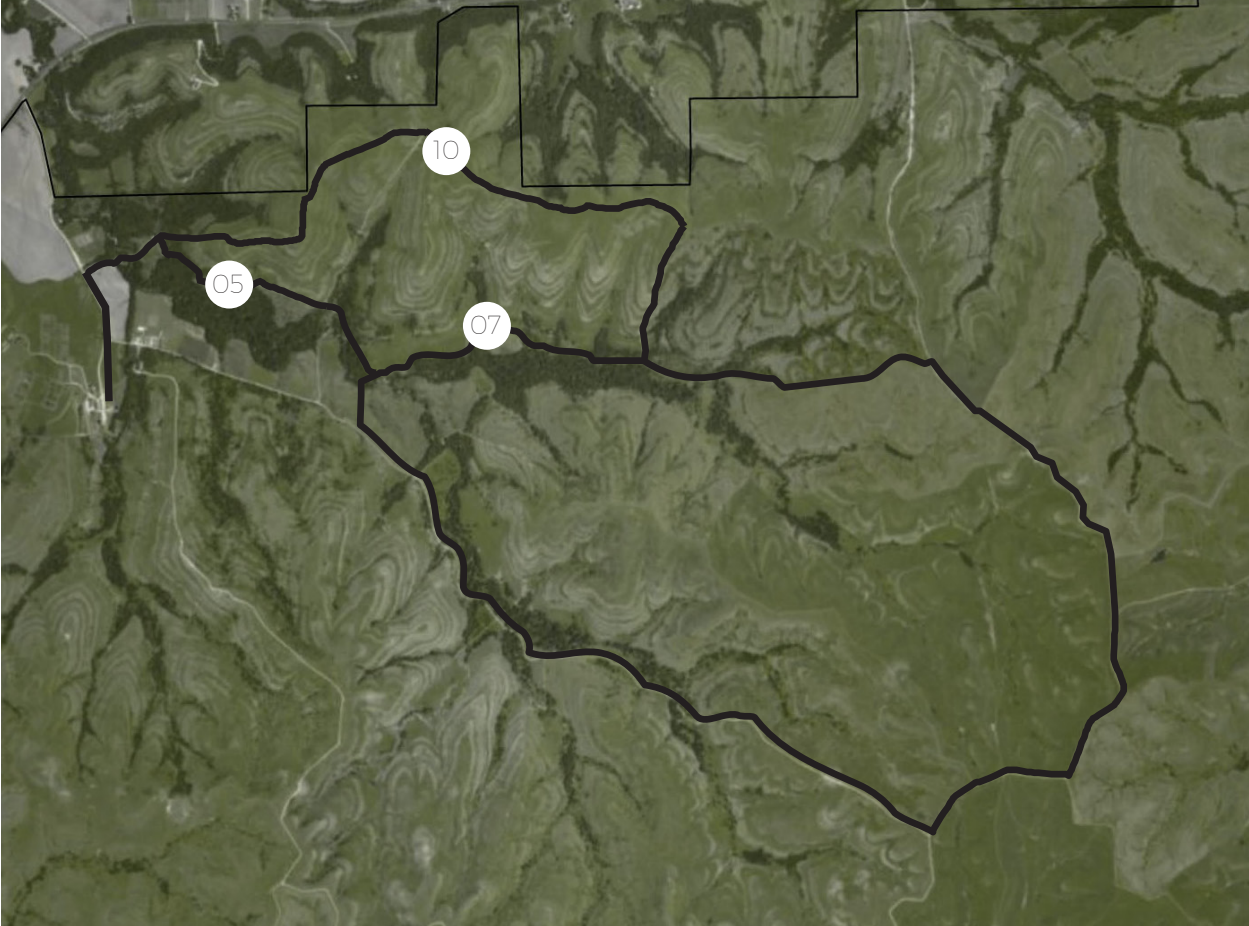
Evaluating action and advocacy of the ecological management practices on the Konza Prairie could be monitored through future organization membership and involvement.



LEVEL-BASED LEARNING

Game presets include a level-based learning approach to focus the visualization content, categorized into badges. Each level is a specific selection of the 16 total checkpoints along the virtual trail loop with a common theme: grazing, prairie burning, vegetation, landform & hydrology, and history. The user may select which badge they would like to earn, which then limits the available checkpoints and evaluation questions to the corresponding badge. Similar to the full game experience, the backpack overview sequence reviews the items collected in the backpack with supplemental information included. Items collected during the level-based approach will be similar, thus reinforcing the selected theme with supplemental information.

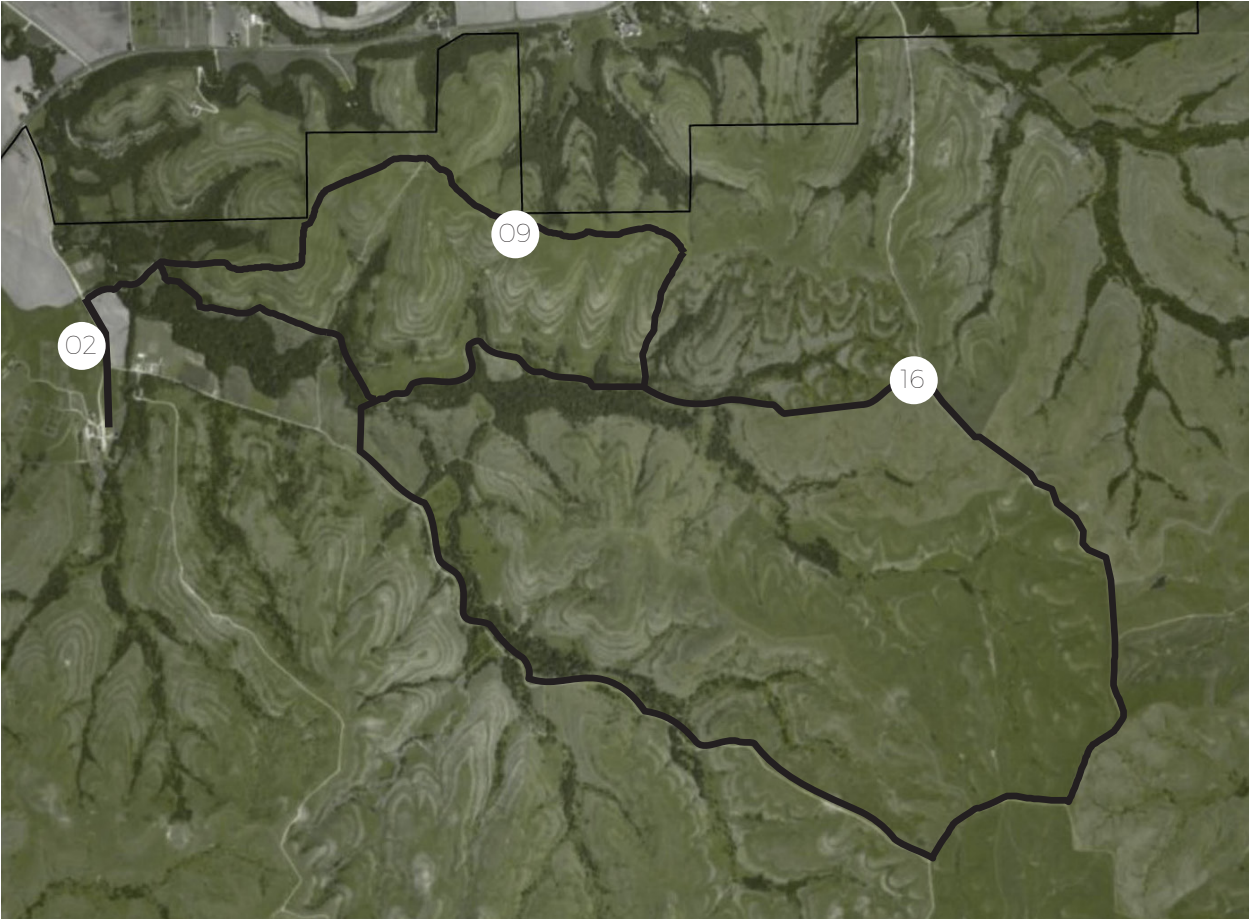
LAND BADGE LEVEL



The Land badge level includes checkpoints 05, 07 and 10. This badge level highlights the cuesta landform of the Konza Prairie, land formation, soil composition, and hydrological features like Kings Creek.

FIGURE 8.4: Land Badge Checkpoint Map
Source: Created by Natalie Webb

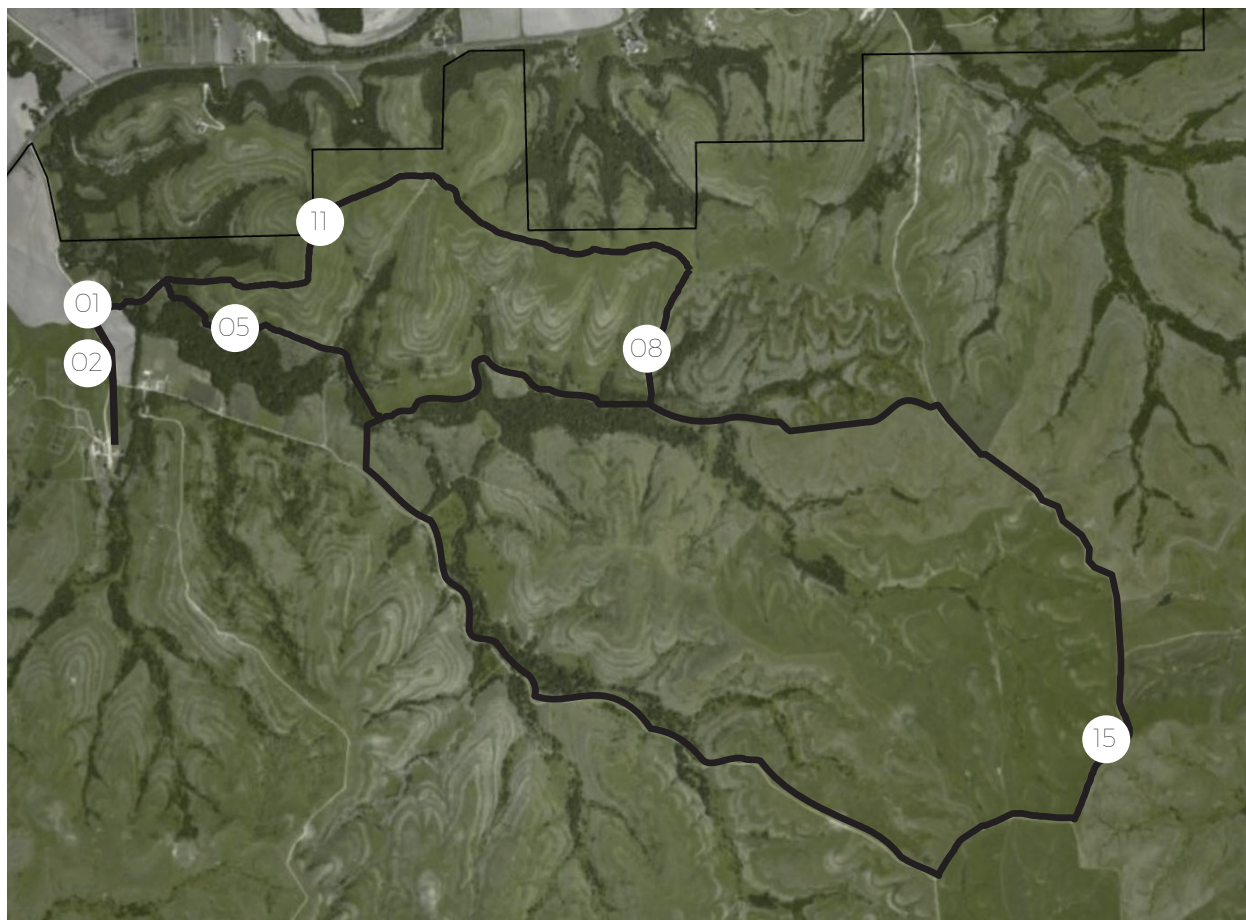
PRAIRIE FIRE BADGE LEVEL



The Prairie Fire badge level includes checkpoints 02, 09, and 16. This badge level highlights the ecological management aspects of prairie burning, burning intervals, and prairie succession due to prairie burning.

FIGURE 8.5: Prairie Fire Badge Checkpoint Map
Source: Created by Natalie Webb
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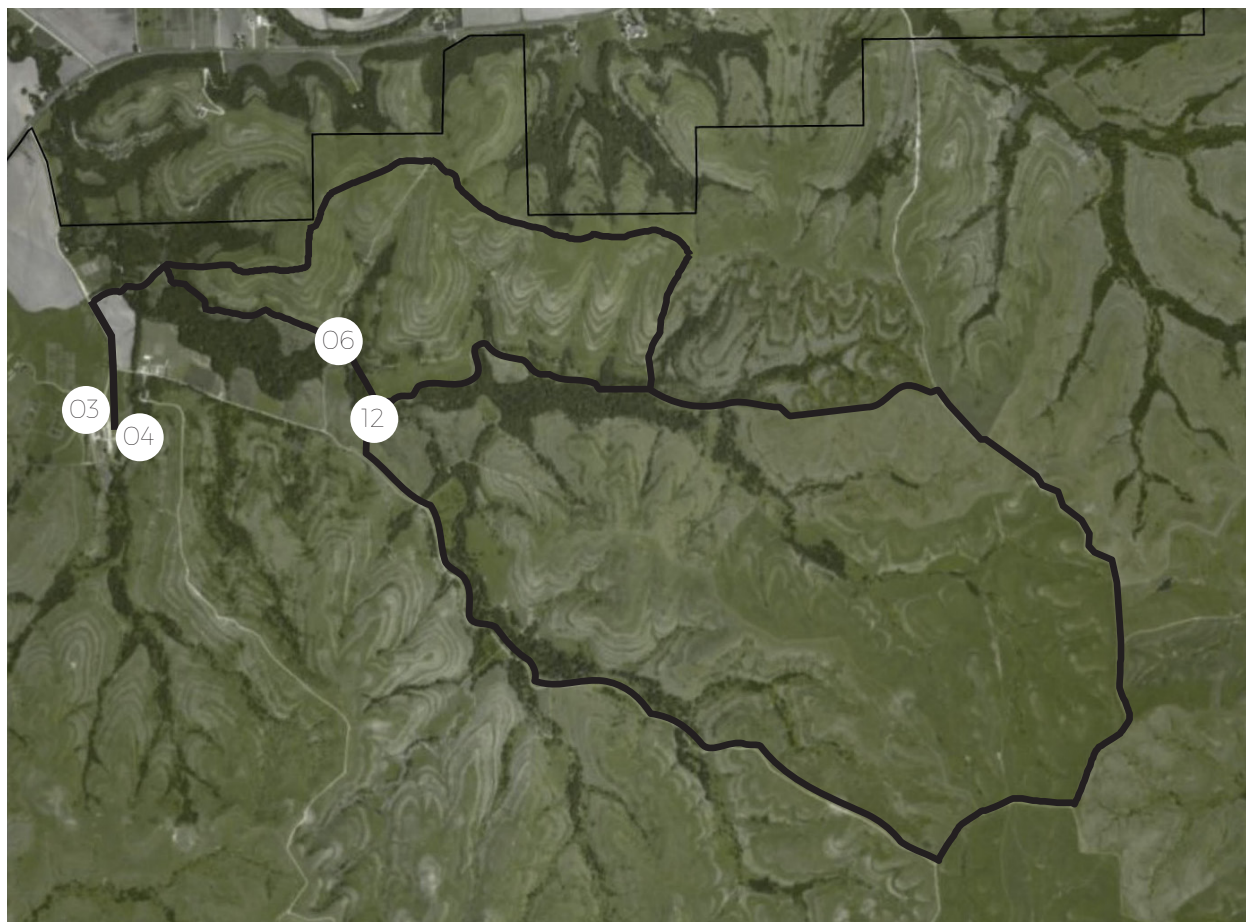
PLANT BADGE LEVEL



The Plant badge level includes checkpoints 01, 02, 05, 08, 11, and 15. This badge level highlights the different prairie types found at the Konza Prairie.

FIGURE 8.6: Plant Badge Checkpoint Map
Source: Created by Natalie Webb

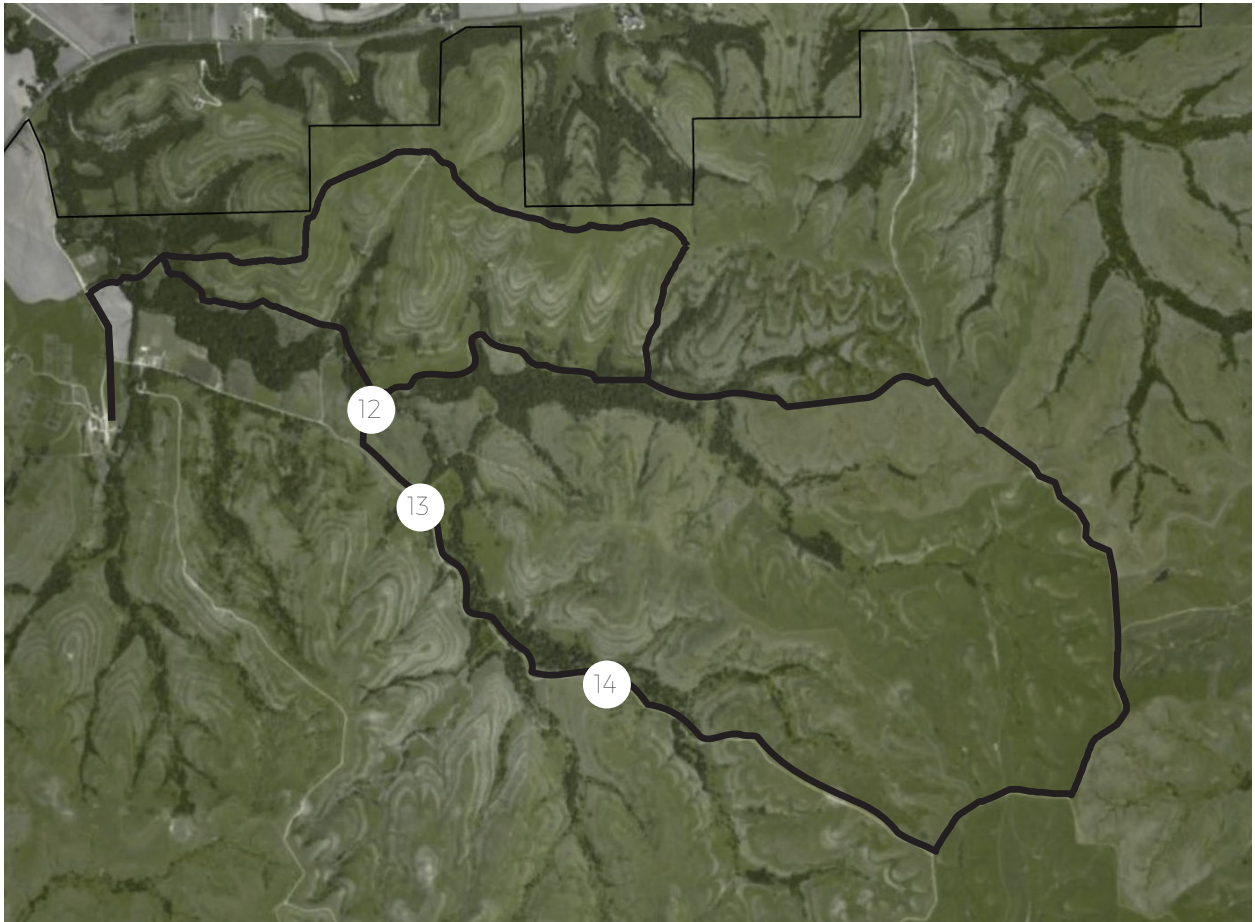
HISTORY BADGE LEVEL



The History badge level includes checkpoints 03, 04, 06 and 12. This badge level highlights the historical aspects of the Konza Prairie, including the Native Americans, Dewey Cattle Company and Hokanson Homestead.

FIGURE 8.7: History Badge Checkpoint Map
Source: Created by Natalie Webb
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GRAZING BADGE LEVEL



The Grazing badge level includes checkpoints 12, 13, and 14. This badge level highlights the ecological management practice of bison grazing, the history of the bison on the Konza Prairie, and prairie succession due to grazing.

FIGURE 8.8: Grazing Badge Checkpoint Map
Source: Created by Natalie Webb



09 **CONCLUSION**



FUTURE OF THE KONZA PRAIRIE 3D LEARNING ENVIRONMENT

The future of the Konza Prairie 3D learning environment has many possibilities. In-depth conceptual storyboarding, user interface design and technology recommendations provide a substantial foundation for the environment to be built and potentially altered for different display technologies. These technologies may include, but not limited to: tablets, computer screens, immersion screens, Hollow Lands (holographic projection), or touch screens.

The 3D learning environment could be built as a future exhibit for local or regional museum facilities, showcasing regional ecosystems to educate a large audience. Positive feedback from local museums has already been received for the conceptual storyboarding of the environment, supporting the potential exhibit.

UNIQUE BENEFITS OF 3D LEARNING ENVIRONMENTS

The Konza Prairie digital environment can be adjusted to fit many different display technologies such as touch tablets, computer screens, large projector screens or phone apps. The specific benefit of using the Oculus Rift technology with the 3D learning environment is the immersive experience into the virtual environment, making the user feel as though they were at the physical site. The immersive nature of the 3D learning environment provides focus on educational aspects, improving information delivery.

Interactive educational components are another unique benefit to 3D learning

environments. Not only is the user immersed into an educational experience, but manipulation of the virtual environment allows them to customize their experience.

Within the customizable environment, the user can absorb a much larger breadth of information that would take years to observe first hand at the Konza Prairie. This provides a comprehensive and efficient way to learn about the visualization focus.

PROJECT SIGNIFICANCE: NEW OPPORTUNITIES FOR 3D LEARNING ENVIRONMENTS IN ENVIRONMENTAL EDUCATION

Exploring the use of visualization technologies in environmental education provides new opportunities to reach a digital-gear generation about important environmental issues. While the future use of 3D learning environments in environmental education appears promising, only the visual representation and concept has been explored. The impact on learning and information delivery has yet to be prototyped or assessed for effectiveness.

Rapid technological developments in display technology and visualization components, such as graphic quality, immersion and interactivity, paired with the urgent need for public education about pressing environmental issues and mitigation practices make 3D learning environment potentially ideal tools for environmental education.



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11

APPENDIX

A

NCS Science, Technology, Society and the Environment

APPENDIX A

Science, Technology, Society & the Environment



The goal that all students should learn about the relationships among science, technology, and society (known by the acronym STS) came to prominence in the United Kingdom and the United States in the early 1980s. The individual most closely associated with this movement is Dr. Robert Yaeger, who has written extensively on the topic (e.g. Yaeger 1996). A study of state standards (Koehler et al. 2007) has shown that STS became common in state science education standards during the first decade of the millennium, with an increasing focus on environmental issues. Consequently, the core ideas that relate science and technology to society and the natural environment in Chapter 8 of *A Framework for K-12 Science Education* (NRC, 2012) are consistent with efforts in science education for the past three decades.

IN THE FRAMEWORK

The Framework specifies two core ideas that relate science, technology, society and the environment: the interdependence of science, engineering and technology, and the influence of science, engineering and technology on society and the natural world.

- The Interdependence of Science, Engineering, and Technology

- The first core idea is that scientific inquiry, engineering design, and technological development are interdependent:

The fields of science and engineering are mutually supportive, and scientists and engineers often work together in teams, especially in fields at the borders of science and engineering. Advances in science offer new capabilities, new materials, or new understanding of processes that can be applied through engineering to produce advances in technology. Advances in technology, in turn, provide scientists with new capabilities to probe the natural world at larger or smaller scales; to record, manage, and analyze data; and to model ever more complex systems with greater precision. In addition, engineers' efforts to develop or improve technologies often raise new questions for scientists' investigations. (NRC, 2012, p. 203)

The interdependence of science—with its resulting discoveries and principles—and engineering—with its resulting technologies—includes a number of ideas about how the fields of science and engineering interrelate. One is the idea that scientific discoveries enable engineers to do their work. For example, the discoveries of early explorers of electricity have enabled engineers to create a world linked by vast power grids that illuminate cities, enable

communications, and accomplish thousands of other tasks. Engineering accomplishments also enable the work of scientists. For example, the development of the Hubble Space Telescope and very sensitive light sensors have made it possible for astronomers to discover our place in the universe, noticing previously unobserved planets and getting even further insight into the origin of stars and galaxies.

The vision projected by the Framework is that science and engineering continuously interact and move each other forward, as expressed in the following statement:

New insights from science often catalyze the emergence of new technologies and their applications, which are developed using engineering design. In turn, new technologies open opportunities for new scientific investigations. (NRC, p. 210)

This reflects the key roles both science and engineering play in driving each other forward in the research and development (R&D) cycle.

THE INFLUENCE OF SCIENCE, ENGINEERING AND TECHNOLOGY ON SOCIETY AND THE NATURAL WORLD

The second core idea focuses on the more traditional STS theme, that scientific and technological advances can have a profound effect on society and the environment.

Together, advances in science, engineering, and technology can have—and indeed have had—profound effects on human society, in such areas as agriculture, transportation, health care, and communication, and on

the natural environment. Each system can change significantly when new technologies are introduced, with both desired effects and unexpected outcomes. (NRC, 2012, p. 210).

This idea has two complementary parts. The first is that scientific discoveries and technological decisions affect human society and the natural environment. The second is that people make decisions for social and environmental reasons that ultimately guide the work of scientists and engineers. As expressed in the Framework:

From the earliest forms of agriculture to the latest technologies, all human activity has drawn on natural resources and has had both short- and long-term consequences, positive as well negative, for the health of both people and the natural environment. These consequences have grown stronger in recent human history. Society has changed dramatically, and human populations and longevity have increased, as advances in science and engineering have influenced the ways in which people interact with one another and with their surrounding natural environment.

Not only do science and engineering affect society; society's decisions (whether made through market forces or political processes) influence the work of scientists and engineers. These decisions sometimes establish goals and priorities for improving or replacing technologies; at other times they set limits, such as in regulating the extraction of raw materials or in setting allowable levels of pollution from mining, farming, and industry. (NRC, 2012, p. 212)

The first paragraph above refers to the

central role that technological changes have had on society and the natural environment. For example, the development of new systems for growing, processing, and distributing food made possible the transition from widely dispersed hunter-gatherer groups to villages and eventually cities. While that change took place over thousands of years, in just the past generation we have seen vast growth in the size of cities along with the establishment of new global communications and trade networks. In 1960 the world population was 3 billion. Today it is more than 6 billion, and thanks to advances in medicine and public health, people are living longer. Additionally, the growth of industrialization around the world has increased the rate at which natural resources are being extracted, well beyond what might be expected from a doubling of world population alone.

The second paragraph emphasizes the limits to growth imposed by human society and by the environment, which has limited supplies of certain non-renewable resources. Together, these paragraphs point the way to new science education standards that will help today's children prepare for a world in which technological change, and the consequent impact on society and natural resources, will continue to accelerate.

HOME AND COMMUNITY CONNECTIONS TO SCHOOL SCIENCE FOR STUDENT DIVERSITY

While it has long been recognized that building home-school connections is important for the academic success of non-dominant student groups, in practice, this is rarely done

in an effective manner. There is a perceived disconnect between the science practices taught in schools and the science supported in the homes and communities of non-dominant student groups. Recent research has identified resources and strengths in the family and home environments of non-dominant student groups (National Research Council, 2009). Students bring to the science classroom “funds of knowledge” that can serve as resources for academic learning when teachers find ways to validate and activate this prior knowledge (González, Moll, & Amanti, 2005). Several approaches build connections between home/ community and school science: (1) increasing parent involvement in their children's science classroom and encouraging parents' roles as partners in science learning, (2) engaging students in defining problems and designing solutions of community projects in their neighborhoods (typically engineering), and (3) focusing on science learning in informal environments.

IN THE NEXT GENERATION SCIENCE STANDARDS

There is a broad consensus that these two core ideas belong in the NGSS but a majority of state teams recommended that these ideas could best be illustrated through their connections to the natural science disciplines. There are a number of performance expectations that require students to demonstrate not only their understanding of a core idea in natural science, but also how that idea is supported by evidence derived from certain technological advances. The connection between these core ideas and specific performance expectations is shown in the crosscutting concept foundation box.

The following matrix summarizes how the two core ideas discussed in this chapter progress across the grade levels.

Interdependence of Science, Engineering, and Technology			
K-2 Connections Statements	3-5 Connections Statements	6-8 Connections Statements	9-12 Connections Statements
Science and engineering involve the use of tools to observe and measure things.	<p>Science and technology support each other.</p> <p>Tools and instruments are used to answer scientific questions, while scientific discoveries lead to the development of new technologies.</p>	<p>Science and technology drive each other forward.</p> <p>Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems.</p>	<p>Science and engineering complement each other in the cycle known as research and development (R&D).</p> <p>Many R&D projects may involve scientists, engineers, and others with wide ranges of expertise.</p>

Influence of Engineering, Technology, and Science on Society and the Natural World			
K-2 Connections Statements	3-5 Connections Statements	6-8 Connections Statements	9-12 Connections Statements
<p>Every human-made product is designed by applying some knowledge of the natural world and is built by using natural materials.</p> <p>Taking natural materials to make things impacts the environment.</p>	<p>People's needs and wants change over time, as do their demands for new and improved technologies.</p> <p>Engineers improve existing technologies or develop new ones to increase their benefits, decrease known risks, and meet societal demands.</p> <p>When new technologies become available, they can bring about changes in the way people live and interact with one another.</p>	<p>All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.</p> <p>The uses of technologies are driven by people's needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.</p> <p>Technology use varies over time and from region to region.</p>	<p>Modern civilization depends on major technological systems, such as agriculture, health, water, energy, transportation, manufacturing, construction, and communications.</p> <p>Engineers continuously modify these systems to increase benefits while decreasing costs and risks.</p> <p>New technologies can have deep impacts on society and the environment, including some that were not anticipated.</p> <p>Analysis of costs and benefits is a critical aspect of decisions about technology.</p>

CONCLUSION

In the decades ahead, the continued growth of the world's population along with technological advances and scientific discoveries will continue to impact the lives of our students. Whether or not they choose to pursue careers in technical fields, they will be asked to make decisions that influence the development of technologies and the direction of scientific research that we cannot even imagine today. Consequently, it is important for teachers to engage their students in learning about the complex interactions among science, technology, society and the environment.

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