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EVIDENCE-BASED DESIGN AND DEVELOPMENT OF INTERACTIVE LEARNING UNITS: A MUSEUM CASE STUDY

By

Cordelia Chong

A dissertation

submitted in partial fulfillment

of the requirements for the degree of

Doctor of Arts in the Department of Biological Sciences

Idaho State University

Fall 2017

To the Graduate Faculty:

The members of the committee appointed to examine the dissertation of **Cordelia Chong** find it satisfactory and recommend that it be accepted.

Professor Rosemary Smith
Major Advisor

Professor Charles Peterson
Committee Member

Professor Dorothy Sammons
Committee Member

Professor Rick Williams
Committee Member

Professor Esther Ntuli
Graduate Faculty Representative

June 16, 2016

Cordelia Chong
Biological Sciences
MS 8007

RE: regarding study number IRB-FY2016-367: Using Eye-tracking to Evaluate an Online Museum Learning Module: A Case Study

Dear Ms. Chong:

Thank you for your responses from a previous review of the study listed above. These responses qualify for expedited review under OHRP guidelines. This is to confirm that I have approved your application.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

You may conduct your study as described in your application effective immediately. The study is subject to renewal on or before Jun 16, 2017, unless closed before that date.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; email humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

June 29, 2016

Cordelia Chong
Biological Sciences
MS 8007

RE: regarding study number IRB-FY2016-388: Connecting Formal and Informal Science Learning: A Case Study

Dear Ms. Chong:

I agree that this study qualifies as exempt from review under the following guideline: Category 1: Normal educational practices & settings. This letter is your approval, please, keep this document in a safe place.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

You are granted permission to conduct your study effective immediately. The study is not subject to renewal.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; fax 208-282-4723; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

February 23, 2017

Cordelia Chong
Biological Sciences
MS 8007

RE: regarding study number IRB-FY2017-183: Evaluation of Selected Online Museum Learning Units

Dear Ms. Chong:

I agree that this study qualifies as exempt from review under the following guideline: Category 2: Anonymous educational tests, surveys, interviews, or observations. This letter is your approval, please, keep this document in a safe place.

Notify the HSC of any adverse events. Serious, unexpected adverse events must be reported in writing within 10 business days.

You are granted permission to conduct your study effective immediately. The study is not subject to renewal.

Please note that any changes to the study as approved must be promptly reported and approved. Some changes may be approved by expedited review; others require full board review. Contact Tom Bailey (208-282-2179; fax 208-282-4723; email: humsubj@isu.edu) if you have any questions or require further information.

Sincerely,

Ralph Baergen, PhD, MPH, CIP
Human Subjects Chair

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I want to express my gratitude to **Dr. Rick Williams**, who came up with the idea for my project. With his roles as a biology professor, the research curator of the Ray J. Davis Herbarium as well as the main curator of the Evolving Idaho exhibit, Dr. Williams provided valuable input, both for this project and future directions. I am especially thankful for his careful reading of my dissertation and his sense of humor during my committee meetings.

I want to acknowledge the support from **Dr. Charles Peterson**, an experienced biology professor who also happens to be a talented photographer. Like both Dr. Smith and Dr. Williams, Dr. Peterson has always been active in outreach activities and believes students learn best through hands-on experience. Even so, he appreciates technology and embraces digital learning. Likewise, I appreciate the many ideas from **Dr. Jane Strickland** and **Dr. Dorothy Sammons**, who are well-versed in multimedia learning. Dr. Strickland encouraged me to try out the state-of-the-art eye tracker on campus and Dr. Sammons helped me design the comparison study.

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For data analysis, I made full use of what I learned in **Dr. Ernest Keely**'s biometry class. Next, I want to take this opportunity to thank the following professors for their words of encouragement: **Dr. Gene Scalarone**, **Dr. Dave Delehanty**, **Dr. Keith Reinhardt**, and **Dr. Mark Austin**. Like other graduate students, I received a lot of help from **Noreen King**, **Pam Christensen**, **Cindy Russell**, **Sacha Johnson**, **Emily Baergen, Reiko Scalarone**, and **Jessica Fultz**. Also, it was my pleasure to have interacted with the following past and current graduate students: **Kaleb Heinrich**, **Ayo Hodonu**, **Roger Long**, **Dave Huber**, **Stephanie Zorio**, **Amanda Hillis**, **Kaylee McCullough**, **Dave Bush**, **Ehren Moher, Kelsey Robson**, **Kole Bowman**, **Jon Dudko**, **Pam O'Hearn**, **Harman Sharma**, **Verona Nicolae**, **Jing-Jing Li**, **Kshitij Shrestha**, **Tiffany Smith**, **Maryam Kalifa**, **Ruth MacNeille**, **Jessica Whitaker, Janet Braun**, **Arin Esterbrook**, **Tyson Hallbert**, **Cody Feldman**, **Hope Owens**, **Kendra Eaton**, **Sophie Hill**, and **Steven Augustine**. I was fortunate to collaborate with **Diantha Smith**, a dedicated English professor who is equally convinced of the value interactivity in learning. Last but not least, I want to thank my parents and my sisters, who are cheering me on from far away.

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EVIDENCE-BASED DESIGN AND DEVELOPMENT OF INTERACTIVE LEARNING UNITS: A MUSEUM CASE STUDY

Dissertation Abstract – Idaho State University (2017)

My project pursues the broad question of how museums can capitalize on the limitless digital learning opportunities by exploring a strategy that addresses the top barriers faced by most of the 35,000 U.S. museums: limitations in the areas of funding, staff expertise, and staff time. I analyzed nearly 900 websites of natural history museums and science centers. I found that only 2% of the websites offer interactives, and most of them are in top one-third of operating budgets within their discipline groups. Thus, most museums have yet to benefit from interactive digital learning on their websites.

I provide a rationale for interactives on museum websites as: (1) add museum online offerings, (2) connect formal and informal learning, (3) motivate learning in bite-sized portions, and (4) repurpose content. I pinpointed three characteristics of a practical digital learning platform that would appeal to most museums: essential (friendly budget, gentle learning curve, and easy editing approach), supporting (assessment choices, learning analytics, and design choices), and enhanced (cross-platform compatibility, embeddable webpages, and social media) features.

To obtain a cohesive view of the overlapping research findings in learning and design principles originated from non-museum contexts, I propose the 4R model with four stages (Reception, Reflection, Review, and Retrieval) by integrating the Zull-Kolb learning model, Cognitive Learning Theory, and multimedia design principles, which are related to our capacity to learn. I also constructed the A.S.S.I.S.T. framework (Appeal, Style, Structure, Interest, Support,

and Tasks) by consolidating design conditions that can promote our motivation to learn. Then, I integrated the A.S.S.I.S.T framework into the 4R model to combine the cognitive and motivational aspects of learning.

To apply the above evidence-based principles, I used Office Mix® to design eight interactive learning units in collaboration with the Evolving Idaho exhibit at the Idaho Museum of Natural History. I evaluated the learning units through formative and summative usability testing using surveys and eye-tracking, and comparison with a professionally-created learning unit. I demonstrated that educators at a smaller institution can apply design principles using my approach to develop learning units comparable to similar resources designed by a team of professionals.

Chapter I: Introduction

"Anytime, anyplace, anywhere." Most people do not know that this iconic slogan originated from a Martini campaign back in the 1970s (Laidlaw, 2013). In the year 2017, variants of the slogan are pervasive in marketing campaigns by media outlets, online retailers, and many others. Ubiquitous technology is not just transforming the business world but our society as a whole – digital media are reshaping the way we work, learn, and socialize. In this dissertation, I use the term "**new digital media** or technology" to include platforms (e.g. websites and applications) and formats (e.g. text, audio, video and images) that have emerged on digital devices such as desktop computers, laptops, tablets, and smartphones in the last two decades, which are considered relatively new at the moment of this writing.

Given that people can access information anytime and anywhere through new digital media, learning opportunities are no longer just available at learning institutions but instead are expanding with the new digital frontier (Bonk, 2009). Even if one is not privy to the complex systematic changes in corporations, government agencies, and school systems to better harness the potential of new digital media (World Economic Forum, 2016), one is likely aware of the rise of Web-based alternative informal learning environments (Selwyn, 2007).

The term "informal learning" broadly refers to any learning that takes place without a formal curriculum, regardless if it takes place face-to-face or online, and if it involves organized or self-directed activities. In his book, *Informal Learning: Rediscovering the Natural Pathways that Inspire Innovation and Performance*, Cross (2011) uses the analogy of the formal bus and the informal bike. On the formal school bus, the bus driver picks the route and the speed, but the learner on an informal touring bike has control over the entire journey. With expanding digital learning tools, informal learning is gaining more recognition now, than ever before.

The World Wide Web or simply the Web is a way of accessing information over a global system of networks known as the Internet, which started with Web 1.0, a static platform for users to browse and download information. The more dynamic Web 2.0 allows users to participate in a wide range of Web-based activities (e.g., blogs, wikis, social media), thus setting the stage for a growing online participatory culture. As a result, there is now a call for the educational use of Web 2.0 in the context of informal learning, where learners are both consumers and contributors (reviewed by Song & Lee, 2014).

The published information provided by an unpaid contributor to a website is known as **user-generated content (UGC).** The information might be a photo, video, blog post, or simply a comment. The appeal of UGC is undisputed – in particular, people are interested in the opinions of their friends and family as well as other users/consumers (Van Dijck, 2009). As a result, institutions and organizations have to search for new strategies as their roles as information gatekeepers slowly fade away (Johnston et al., 2016).

Like other organizations, museums are not immune to the disruptions and missed opportunities caused by the changing digital landscapes. In this dissertation, I use the terms "museum" and "cultural institution" interchangeably to represent informal learning organizations. In his book, *"Best of Both Worlds: Museums, Libraries, and Archives in the Digital Age"*, then Secretary of the Smithsonian Institution G. Wayne Clough (2013) put out a call for action:

> Today digital technology is pervasive, its use, particularly by the world's youth, is universal; its possibilities are vast, and everyone in our educational and cultural institutions

> is trying to figure out what to do with it all. It is mandatory that museums, libraries, and archives join with educational institutions in embracing it (p.71).

In a 3-year study (n= 891, 964, 984), the Arts Council of England (2015) identified the five key organization functions for new digital technology as (1) business and operational models, (2) content creation, (3) distribution and exhibition, (4) marketing and audience development, and (5) preserving and archiving. The Institute of Museum and Library Services (IMLS) conducted a similar survey (n=537) where Apley et al. (2011) identified the primary technology-based activities in museums across all the discipline groups as (1) organizational development, (2) programming, (3) exhibitions, (4) online resources, and (5) digitization/collections.

No discussion of digital content creation is complete without the connecting powers of social media, which are Web-based tools that allow the sharing of text, photos, and videos. Like many individuals and businesses, nearly all cultural institutions have jumped on the social media bandwagon. A survey of art organizations by the Pew Research Center (2013) revealed that ninety-seven percent of the survey respondents are active on social media.

Initially designed for non-pedagogical purposes, many social media platforms have since gained prominence as alternative informal learning tools. Case-in-point: YouTube is now a popular repository of digital content used for both formal (e.g., Snelson, 2011) and informal learning (e.g., Meyers, 2014). The synergy between social media and informal learning will only grow stronger with the surging popularity of mobile devices, as highlighted by Johnson et al. (2016) in *The NMC Horizon Report: Higher Education Edition:*

> As the Internet has brought the ability to learn something about almost anything to the palm of one's hand, there is an increasing interest in the kinds of self-directed, curiosity-based

> learning that have long been common in museums, science centers, and personal learning networks (p.22).

In line with this trend, there is a growing interest among educators to investigate the use of social media in the context of higher education (e.g., Dabbagh & Kitsantas, 2012) as well as museum learning (e.g., Fletcher & Lee, 2012, Kidd, 2011; Padilla-Meléndez & del Águila-Obra, 2013).

If the high reliance of the public on technology to communicate and find information is the major driving force behind the seemingly unstoppable rise of social media, how can museums think strategically and creatively about how best to leverage new digital media to set museum learning apart from the other informal learning spaces?

To that end, the Smithsonian Institution launched the Learning Lab to provide public access to the enormous digital resources associated with the famed institution (Lewis, 2016). In the meantime, the well-funded Metropolitan Museum of Art is deploying a long list of digital strategies that will transform the well-known cultural institution into a full-fledged media company (Baker, 2015). The digital transition of a museum largely depends on its budget because some museums are investing more in a single technology project than other museums have in their entire annual operating budget.

There is no lack of creativity in the museum world. Unfortunately, many of the latest digital strategies (e.g., digital games, virtual reality, augmented reality) implemented by well-funded museums are out of reach for smaller organizations. In his investigation into government funding for museums in the United States, artist and author Isaac Kaplan (2016a) regrets how headlines on a few major institutions gave the public a “false impression of the health of U.S. institutions as a whole” because there is a growing divide between big and small museums: “Taxpayer-funded, federal support of museums in the United States benefits a relative few institutions—and the larger and more prestigious those museums are, the more likely they are to get funding."

Without a national registry, the best estimates for the number of museums in the United States come from the Institute of Museum and Library Services (IMLS), an independent government agency. Ingraham (2014) reported that out of the 35,000 active museums in the United States (Figure 1.1), the majority are found in small towns and rural areas: "Of the roughly 25,000 museums with income data in the file, 15,000 of them reported an annual income of less than $10,000 on their latest IRS returns."

When it comes to IMLS funding of small museums, Apley et al. (2011) stated that "large museums have both applied for and received MFA grants in greater numbers than medium-sized and small museums." MFA stands for Museums for America program, the IMLS flagship initiative that provides grants for exhibitions and other museum projects. Kaplan (2016a) was assured there have been efforts to counter the funding inequalities within the MFA program.

However, a former high-level IMLS staffer confided in Kaplan (2016a) that, "You're not going to find a program at the federal level that uniquely identifies and targets those [small] institutions for support." This, according to the insider, was due to the need-blind structure where funding decisions are based on "the reputation of the director, the status-honor of the institution, and quality of the written proposal." In short, IMLS is funding well-funded institutions, thus "solidifying and exacerbating inequities already present in the system." As of now, no systematic review of MAP's impact on small museums has ever been conducted, so the claims of the insider cannot be challenged.

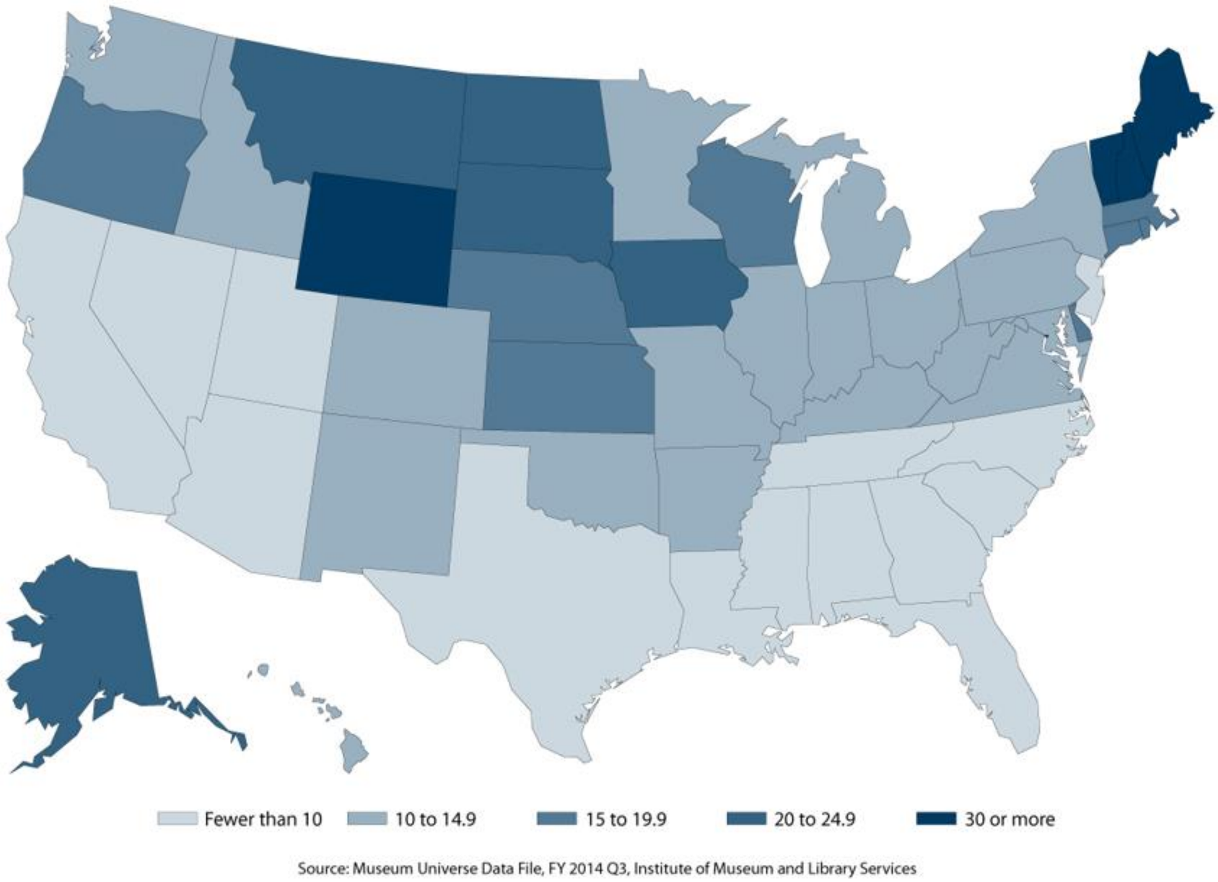

Figure 1. Museums of all disciplines (per 100,000 population) by state, FY 2014. Retrieved from https://www.imls.gov/assets/1/AssetManager/MUDF_StateMap_2014q3.jpg

As the director of the Center for the Future of Museums, Elizabeth Merritt appreciates small museums: "Museums are, if anything, more important in those small rural communities than they are in a big [city] because the small local historical society or the small nature center has an outsized impact on the people who live there." Merritt urges small museums to demonstrate value to their communities and attempts to lessen the alarm raised by Kaplan (2016a): "[Small] museums are the proverbial cockroach in the nuclear winter: you can't kill them."

Statement of the Problem

These are challenging times for museums as public expectations change in this era of digital distractions. The Institute of Museum and Library Services (2014) estimated that there are around 35,000 museums in the United States, and according to Kaplan (2016a), many of them are smaller museums that face dwindling sources of funding, with no signs of relief: "Scarcer public funds, allocated without the influence of objective data, could well mean that stagnation is the new norm as a rapidly urbanizing country watches its heartland ail."

Consultants for local museums sounded the alarm that "small museums lack all of the new technology platforms and as a result, within 3-5 years most small museums will likely fall further behind the industry and become less relevant to the intended audience" (Museum and the Web, 2015). The same sense of urgency was expressed by Clough (2013): "While it is true that the traditional role of our cultural institutions is still valued by the public and is needed, they must find ways to accommodate digital technology or risk becoming marginalized" (p. 6).

At a time when new digital media offer museums new opportunities for audience engagement, technology has paradoxically challenged museums to bring discovery and learning to new heights. Crow and Din (2010) expressed this sentiment by reminding museum educators that "museum visitors have now come to expect an array of online offerings from museums, just as they have come to expect online offerings in other aspects of their daily lives" (p.161). Clough (2013) presented the challenges in the following questions:

> How can we prepare ourselves to reach the generation of digital natives who bring a huge appetite — and aptitude — for the digital world? Are we capitalizing on the limitless

> possibilities that digital technology creates by applying it in innovative ways across our institutions? (p.2).

Museums face many barriers when it comes to applying the seemingly endless possibilities of digital technology. Specifically, several reports (e.g., The MacArthur Foundation, 2011; The Pew Research Center, 2013; Arts Council England, 2015) have uncovered the prevailing barriers that prevent many informal learning organizations from expanding the range and quality of their digital resources as limitations in the areas of funding, staff time and expertise. In light of this, how can small museums maintain their unique qualities while at the same time adding value in this digital age?

As museums continue to develop their online presence, research efforts have concentrated mainly on the design of museum websites (e.g., Pallas & Economides, 2008; Lin, Fernandez & Gregor, 2012; Lopatovska, 2015; Capriotti, Carretón & Castillo, 2016). However, simply having a website is no longer enough (Proctor, 2010; Waters & Feneley, 2013). On top of that, there has been very little attention given to strategies that can overcome the top barriers faced by most museums. So even after a small museum has set up a website, there is little help for museum educators who want to take up the challenges put forth by Clough (2013):

> The trick is to find the means to balance what is good about the long-established embodiment of museums, libraries, and archives with the virtues offered by digital technology, and to do it seamlessly. It is easier said than done, given that resources for our cultural institutions are under stress and their bench of digital talent is thin (p. 63).

Purpose of the Study

The main objective of this study is to address the knowledge gap – an effective digital learning strategy for small museums facing limitations in the areas of funding, staff expertise, and staff time. Such a digital strategy should conform to the descriptions given in *The NMC Horizon Report Museum Edition* (Freeman et al., 2016)*:*

> Digital strategies are not so much technologies as they are ways of using devices and software to enrich education and interpretation, whether inside or outside of the museum. Effective digital strategies can be used in both *formal* and *informal learning*; what makes them interesting is that they transcend conventional ideas to create something that feels new, meaningful, and 21st century (p.34).

To put it another way, an effective digital learning strategy does not necessarily involve the latest digital technology; rather, it is about exploring existing digital tools that Clough (2011) said can "revolutionize both the presentation of information and the way we access it, as well as a new generation of users who have embraced it and represent a ready audience" (p.3).

To discover discipline-specific trends of museum digital learning, this dissertation focuses on cultural institutions with informal science education at the heart of their operations. Though this limits the applicability of the findings and analysis to some degree, I anticipate this model will serve those who do similar work for cultural institutions.

Research Questions

The scope of this study is at the intersection of several research disciplines, including online learning, multimedia learning, museum learning, and to a lesser extent, informal science education. The following research questions set the boundaries for this dissertation:

1. What proportion of the natural history museums and science centers in the United States offers interactive learning resources on their websites, and to what extent?
2. What is the rationale for interactive learning resources on museum websites?
3. What are the characteristics of a practical museum digital learning platform?
4. How to apply evidence-based principles to the design and development of interactive learning resources on museum websites?
5. How do interactive learning units developed by educators at smaller institutions compare with similar resources developed by a team of professionals?

Significance of the Study

Organizations with a long history of providing informal learning are now in a unique position to connect students to new topics outside of their academic focuses because informal learning has gained tremendous recognition in recent years, as highlighted by Johnson et al. (2016) in the *NMC Horizon Report Higher Education Edition*: "As the internet has brought the ability to learn something about almost anything to the palm of one's hand, there is an increasing interest in self-directed, curiosity-based learning."

In the next few years, teaching and learning will likely be a combination of formal and informal learning supported by new digital media, as recommended by Adams et al. (2017) in the *NMC Horizon Report Higher Education Edition*:

> Many experts believe that blending formal and informal methods of learning can create an environment that fosters experimentation, curiosity, and creativity. Solving this challenge requires leaders to articulate its significance and mobilize institutions to integrate informal learning into their curriculum.

While museums have an overall sense that their educational roles are even more important in this digital age than before (Center for the Future of Museums, 2013), Clough (2013) asked the challenging question: "What is the future role of museums, archives, and libraries in a digital world with an insatiable appetite for information and knowledge?" (p.18).

Organization of the Dissertation

Chapter I: Introduction

The first chapter introduces the research topic, presents a statement of the problem, outlines the main purpose of the dissertation, and describes the organization of the dissertation chapters.

Chapter II: Museum Website Content Analysis

The chapter presents the analysis of interactive learning resources on the websites of nearly 900 natural history museums and science centers in the United States.

Chapter III: The Rationale for Interactive Learning Units on Museum Websites

A major portion of this chapter comes from a published article (Chong & Smith, 2017) and presents an overview of interactivity in digital learning and discusses the rationale for interactive learning units on museum websites: adding to museum online offerings, connecting formal and informal learning, motivating learning in bite-sized portions, and repurposing content.

Chapter IV: The Characteristics of a Practical Museum Digital Learning Platform

This article discusses the essential (budget-friendly, gentle learning curve, fast editing approach), supporting (self-assessment choices, design choices, learning analytics), and enhanced (cross-platform compatibility, embeddable webpages, social media sharing,) features of a practical museum digital learning platform.

Chapter V: Office Mix as a Practical Museum Digital Learning Platform

This article documents the challenges, the opportunity, the approach, and the outcome of using Office Mix®, a free add-on software to PowerPoint 2013, as a digital learning platform for evidence-based design and development of interactive learning units on the website of the Idaho Natural History Museum (INHM).

Chapter VI: Conclusions and Future Directions

The final chapter of this dissertation summarizes the key findings and study limitations, and presents recommendations for integrating interactive museum learning resources into classroom learning as well as citizen science projects.

Chapter II: Museum Website Content Analysis

By looking at our own experience – at home, in public spaces and at work – we can see how new digital media are fundamentally reshaping our lives. For museums, the aim is to extend its relationship with visitors beyond the museum's wall. To establish its Web presence, the museum looks to its website, social media, and mobile apps to engage visitors. In particular, museums use new digital media to generate learning resources. The aim of this article is to gain a better understanding of the status of digital learning on museum websites today.

Drawing from the views of 71 museum professionals from around the world, the Archives Libraries Museums (2016) identified that using digital technology to provide educational opportunities is a priority of 86% of the survey respondents. The Pew Research Center (2013) conducted a survey to understand how art organizations (n=1,244) supported by the National Endowment for the Arts (NEA) were using new digital technologies to connect with the public. This report found that only 22% of the survey respondents provided educational resources on their websites (p.3).

To shed light on the specific online resources provided by museums, the Institute of Museum and Library Services (IMLS) surveyed museums (n=537) that received funding from the Museums for America (MFA) program. Apley et al. (2011) reported that 54% of survey respondents invested in online resources, most frequently on updating or creating a new website by doing the following: (1) creating new digital content, (2) converting to digital content, (3) repurposing digital content, and (4) digitizing collections (p.42-44).

The Arts Council England (2015) carried out a longitudinal survey between 2013 and 2015 (n= 891, 964, 984) so researchers can "reflect on how much the sector has changed since 2013." Importantly, the report concluded that the use of new digital technology for publishing content on museum websites such as blogging has become less important among the survey respondents, but the importance of new digital technology for marketing, preserving and archiving remains consistently high. Based on this report, there was a statistically significant decline in educational activities, where only 40% of the surveyed organizations are now producing online classroom resources, down from 65% in 2013. These organizations also scaled back on interactive educational resources, from 39% to 25%.

Thus far, the most extensive research projects to discover organizational efforts related to digital media and learning in after-school programs, libraries, and museums are supported by the MacArthur Foundation (2011), as part of its $50 million initiative. The report (n=not specified) does not provide any quantitative data but instead highlights “examples of the diverse ways in which organizations approach and integrate digital media and technology into their youth programs, practices, and philosophies.”

Not measured in all the above studies is the size of the organizations that participated. Typically, museum size is defined by dividing operating budgets within each of the nine discipline groups (Figure 2.1) into equal thirds in defining small, medium, and large museums (Table 2.1), as suggested by Apley et al. (2011). The size of a museum is an important factor because there is a growing divide between big and small museums where well-funded museums may invest more in a single technology project than smaller museums have in their entire annual operating budget (Kaplan, 2016a). The operating budgets of survey respondents could explain why one study reported that only 22% survey participants provide digital educational resources (Pew Research Center, 2013), while other studies reported that 40% (Arts Council of England, 2015) and 54% (Apley et al., 2011) of their survey respondents offer similar resources.

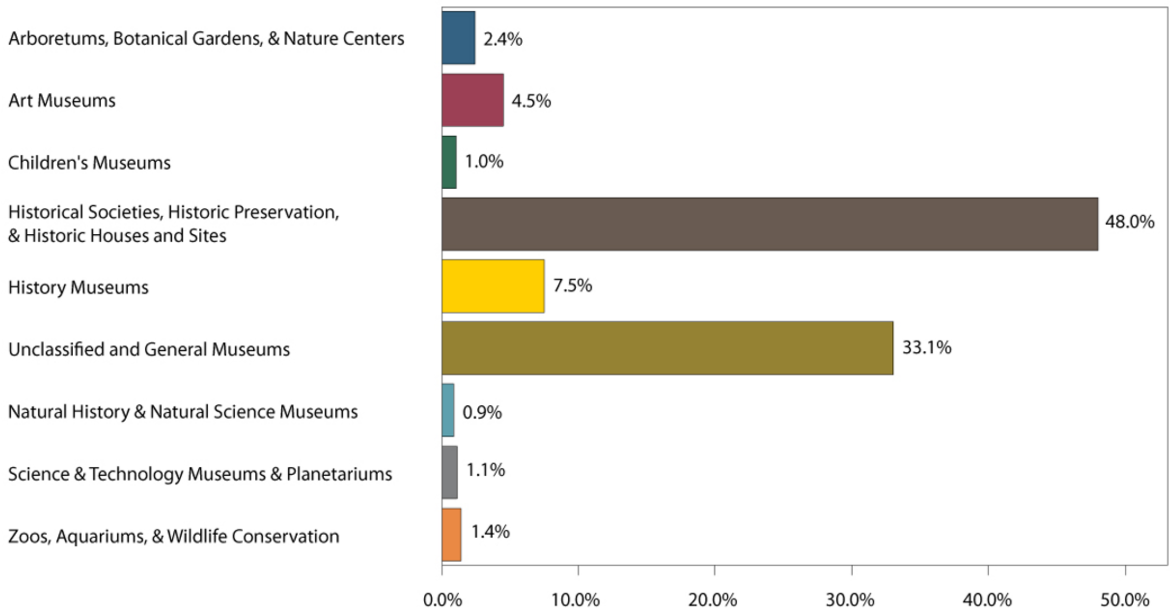

Figure 2.1 Distribution of museums by discipline in 2014. Retrieved from https://www.imls.gov/assets/1/AssetManager/MUDF_TypeDist_2014q3.jpg

Importantly, the above studies identified the top three barriers to any digital initiatives at cultural organizations as limitations in the areas of funding, staff time, and staff expertise. To better understand the top barriers, it is worthwhile to glean the comments collected in the survey conducted by the Pew Research Center (2013). A major challenge for museums is the constant pressure to secure funds needed to acquire, maintain and upgrade technology: "Technologies are developing faster than we are raising money to implement them, and we're facing a significant setback if we can't keep up" (p.16).

Even in cases where the internet-based tools are free, there are still costs associated with the embrace of technology, such as issues of staff capacity and training: "But the fact is, that to do them correctly and to keep doing them, you need to have someone trained and focused on these tasks" (p.17). Of course, organizations that are in better financial position can simply contract digital projects out, but that is not the case for many museums (p.16).

Table 2.1 Operating Budget Ranges for Museum Discipline Groups (Apley et al., 2011).

	Operating Budget Cut Offs Defining Museum Size		
Museum Discipline Group	**Small**	**Medium**	**large**
Arboretum/botanical garden	Less than $1,002,641	$1,002,641-$2,890,012	More than $2,890,012
Art	Less than $874,555	$874,555-$2,899,092	More than $2,899,092
Children/Youth	Less than $446,430	$446,430-$1,982,699	More than $1,982,699
History	Less than $193,425	$193,425-$761,212	More than $761,212
General	Less than $419,741	$419,741-$2,037,391	More than $2,037,391
Natural history/anthropology	Less than $745,471	$745,471-$2,959,130	More than $2,959,130
Science/technology	Less than $1,063,353	$1,063,353-$5,475,416	More than $5,475,416
Aquarium/Zoo	Less than $3,478,945	$3,478,945-$15,669,330	More than $15,669,330
Nature Center	Less than $383,270	$383,270-$1,024,000	More than $1,024,000

In the event financial resources can be secured, administrators frequently need to determine what investment is most critical and when they can best afford it. This is easier said than done because another major challenge is to keep the established base of constituents and supporters engaged "while trying to reach out to our student participants and younger audience through digital technologies." To manage public expectations, many cultural organizations have to shift balance among staff capacity, expertise, and funding:

> Determining how to address the time and resources required to implement/maintain new digital initiatives while continuing existing activities can be a challenge. Adding new without subtracting something frequently results in attempting to continually do more with static levels of resources/funding (p.15).

More recently, Capriotti, Carretón & Castillo (2016) reviewed the websites of the most visited art museums (n=100) from 24 countries: 60 in Europe, 23 in America, and 17 in the Asia/Pacific region. The authors, whose research area is in information management, wanted to assess whether museum websites are transitioning towards more interactive models (Web 2.0) or if they are maintaining a unidirectional operation (Web 1.0). This study utilized several instruments for in-depth museum website analysis. First, multimedia tools were labeled as either expository (text/images, audio/video) or participatory (external links, interactive resources, and virtual tours). Next, the authors evaluated the multimedia tools based on how they engage online visitors: connecting (very low), sharing (low), reviewing (medium), participating (high), and collaborating (very high). The authors found a relatively low overall interactivity score of 0.83 points (range: 0.71-0.89) on a scale of 0-3 points for the top 100 art museums in the world. Even though 60% of the reviewed museums are located in Europe, the highest interactivity scores were assigned to the American institutions.

Taken together, these studies confirm the value of digital resources on museum websites. Museums want to use new digital media to provide educational opportunities, and they do so by updating their websites with multimedia resources such as images, audio, and video. One major challenge faced by museums in their efforts to effectively integrate new digital contents is the use of interactive and immersive tools. Even though previous studies focused mainly on art organizations, by extension, we can expect museums in other disciplines to face similar challenges. To the best of my knowledge, there is no quantitative data on how natural history museums and science centers in the United States are using new digital technology on their websites.

Methodology

To discover discipline-specific trends of interactive museum educational resources, I conducted a content analysis of museum websites specifically geared toward informal science education to answer the question: "What proportion of the natural history museums and science centers in the United States offer interactive learning resources on their websites, and to what extent?"

At the time of this writing, a national registry of museums does not yet exist, but in 2014, the Institute of Museum and Library Services (IMLS) took the first steps towards establishing such a database by compiling the Museum Universe Data File (Institute of Museum and Library Services, n.d.):

> The Museum Universe Data File is an evolving list of museums and related organizations in the United States. It includes basic information on aquariums, arboretums, botanical gardens, art museums, children's museums, general museums, historic houses and sites, history museums, nature centers, natural history and anthropology museums, planetariums, science and technology centers, specialized museums, and zoos.

At this stage, the Museum Universe Data File is far from comprehensive or accurate:

- **Non-museum organizations are included**. For example, a non-museum organization may be included because it has a museum-like name on its IRS record for tax-exempt organizations. Museum foundations and other non-profit organizations are often included.

- **Museums are listed multiple times.** For example, one museum may be listed on two separate lists, as a science center and a natural history museum. Duplicate records are especially common for museums located within universities (e.g., Idaho State University and Idaho Museum of Natural History are listed separately).
- **Museums are missing.** Some museums listed on the Wikipedia pages for natural history museums and science centers in the United States are not listed in the data file.
- **Museums listed in the general discipline group.** Museums that house collections from two or more disciplines, specialized museums as well as planetariums are placed in the "Unclassified and General Museum Categories." That is the reason natural history and natural science museums are listed as only 0.9% of all museums (Figure 2.1).

To conduct the website content analysis, I reviewed the Museum Universe Data File and two Wikipedia pages ("List of natural history museums in the United States", n.d.; "List of science centers in the United States", n.d.). The Museum Universe Data File only identified 0.9% or 315 entries as natural history museums and science centers, which did not tally with the lists on the two Wikipedia pages. I assume that most of the 12,000 unclassified and general museums actually belong to other discipline groups (Figure 2.1).

By eliminating duplicates and non-museum entries, I narrowed more than 1,500 entries down to a list of 896 websites. The final list includes organizations with widely varying operating budgets in the following disciplines: natural history & natural science museums, science & technology museums, and planetariums. I included the occasional entries of zoos, aquariums, wildlife conservation and nature centers. All entries are organized according to the six geographic regions identified by the American Alliance of Museums (AAM), as shown in Table 2.2. Entries from the following U.S. territories and possessions were excluded: American Samoa (AS), Guam (GU), Northern Mariana Islands (MP), Puerto Rico (PR), and the Virgin Islands (VI).

Table 2.2. The six geographical regions identified by the American Alliance of Museums (AAM).

States	Region
CT, ME, MA, NH, RI, VT	New England
DC. DE, MD, NY, NJ, PA	Mid-Atlantic
AL, AR, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV, PR, VI	Southeast
IL, IN, IA, MI, MN, MO, OH, WI	Mid-West
CO, KS, MT, NE, NM, ND, SD, OK, TX, WY	Mountain Plains
AK, AZ, CA, HI, ID, NV, OR, UT, WA, AS, GU, MP	West

During the website content analysis, I used tabs for “Education”, “Teachers”, “Learn”, “Explore” and related terms to locate any learning resources, before deciding if the resources could be considered interactive. However, I did not assess the degree of interactivity, whether low, moderate, or high; instead, I designated any learning content that allows the learner some control over the flow of information during the learning process as interactive.

Next, I assigned each website to one of the four categories based on the descriptions shown in Table 2.3. Category #1 includes museums that have either a Webpage or a Facebook page but there is no clear indication of any learning resources (Figure 2.2). Category #2 is for museums that offer information about onsite exhibits and programs for visitors and educators, including downloadable pre and post-visit guides (Figure 2.3). Category #3 identifies museums that offer online educational resources for both their physical visitors as well as online visitors (Figure 2.4). Category #4 museums offer non-interactive as well as interactive learning resources (Figure 2.5).

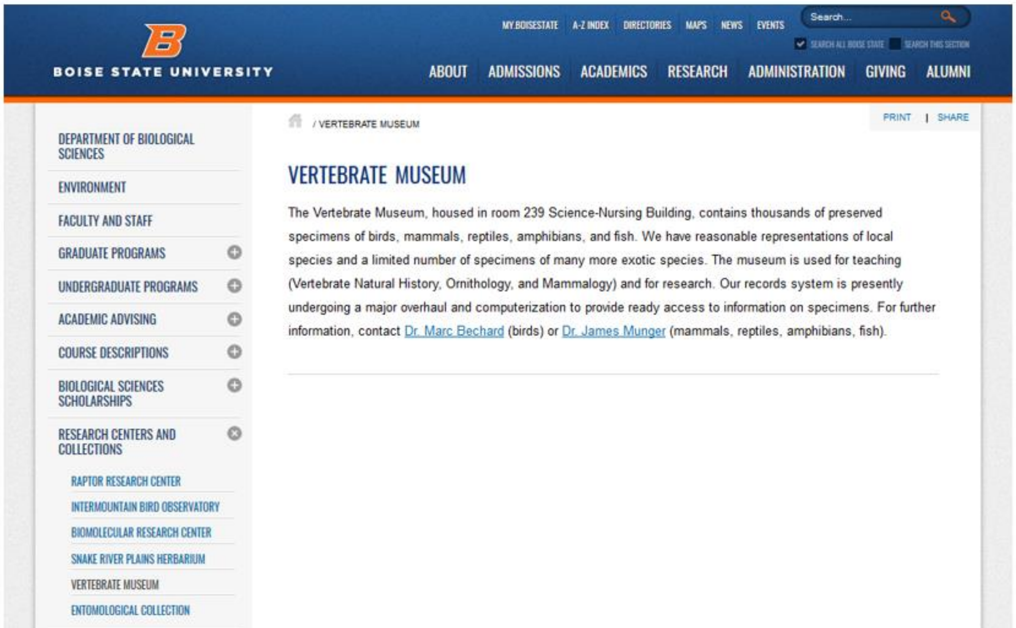

Figure 2.2 A Category #1 museum provides just the basic information.

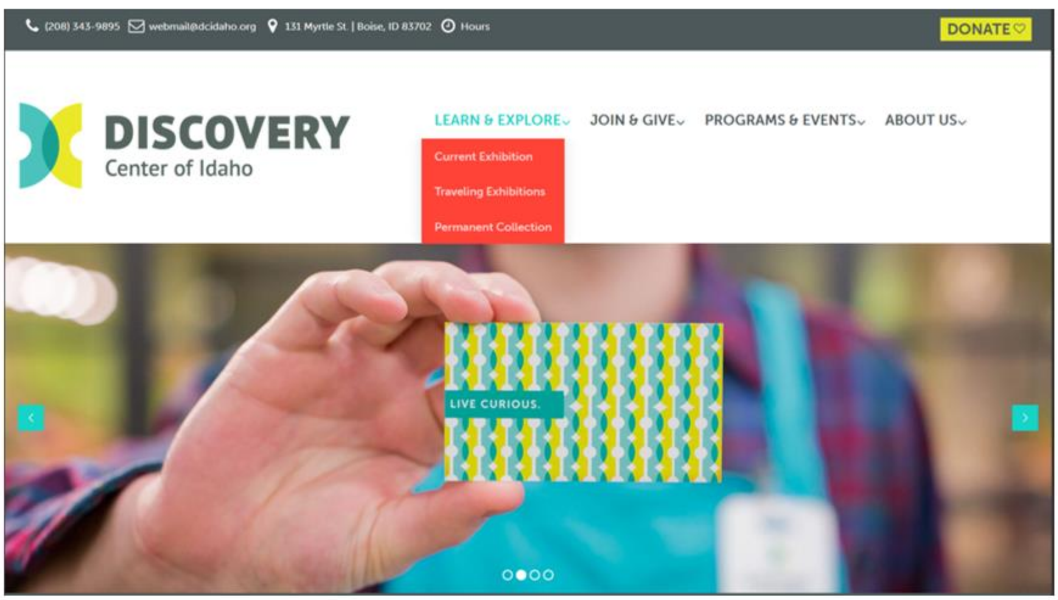

Figure 2.3 A Category #2 museum provides information and resources related to onsite activities and programs.

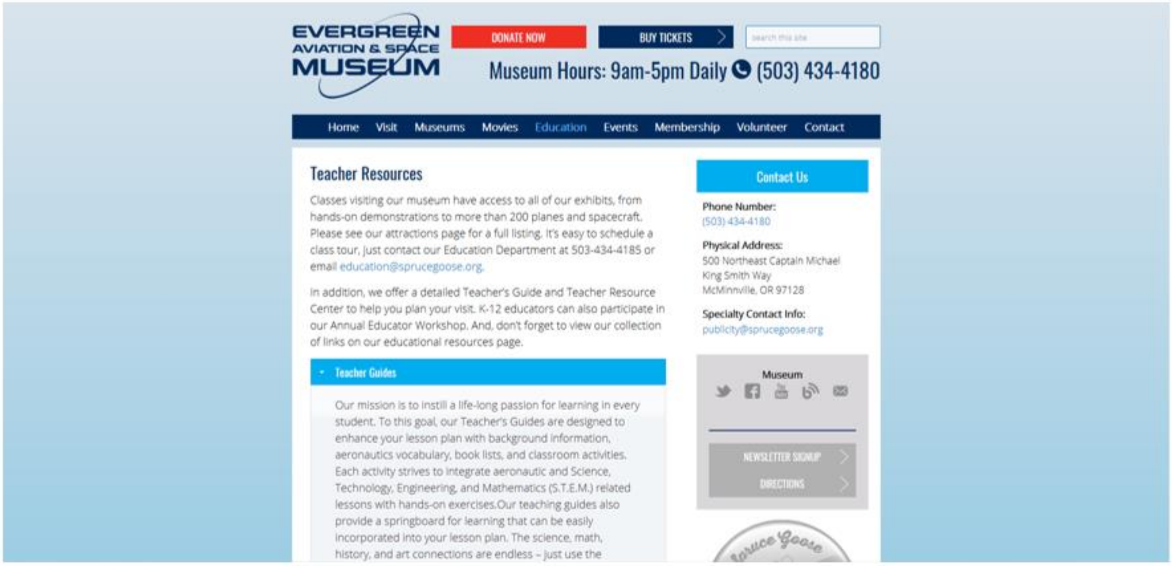

Figure 2.4 A Category #3 museum provides resources for both onsite and online visitors.

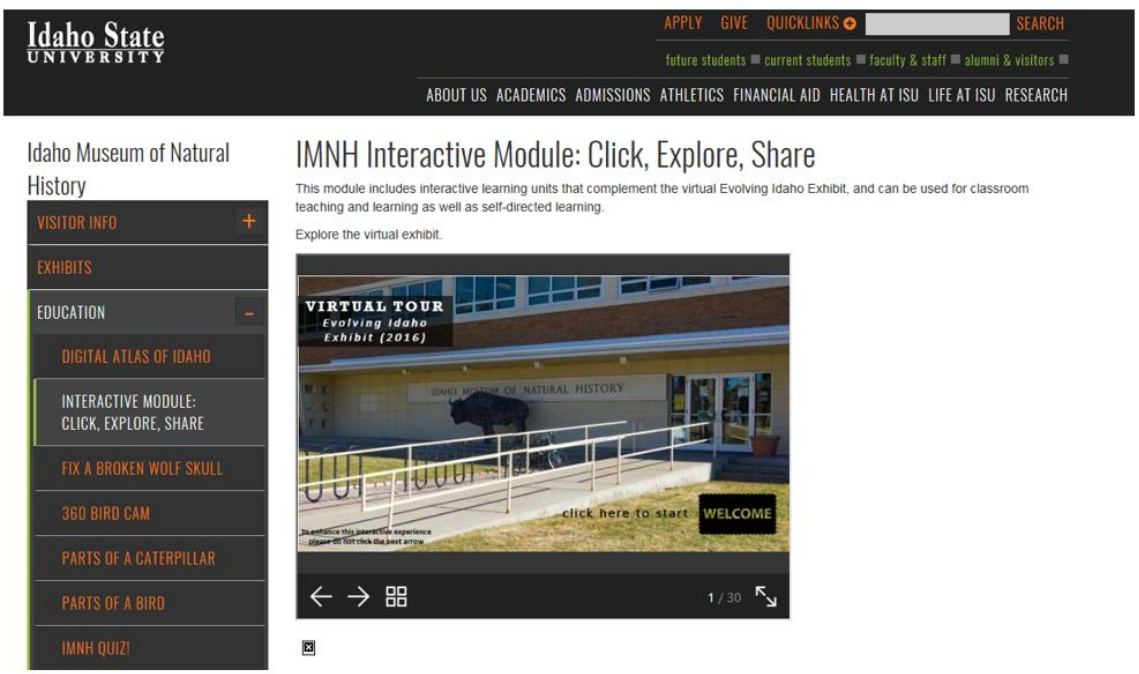

Figure 2.5 A Category #4 museum offers interactive learning resources.

To determine if there is a difference in the operating budgets of museums in the four categories, I used the R statistical software to perform one-way analysis of variance (ANOVA). However, budget information for many entries, especially the Category #1 museums, is not available. For consistency, I decided to only use the Museum Universal Data File even if budget information can be obtained from other sources. Out of the sixteen Category #4 museums, I only found the budget information for ten entries. To make sure that each category has an equal sample size, I randomly selected ten entries from Categories #2 and 3 for data analysis. This was done by using a random number generator. Due to missing budget information, the random selection of entries had to be repeated until enough entries for Categories #2 and 3 were identified.

Results

As shown in Table 2.3, about 12% of the entries have either a Webpage with basic information, such as hours of operation and location, or a Facebook page (Category #1). The majority of museums (70%) maintain a website to highlight onsite programs and activities available for visitors and educators (Category #2). Approximately 16% of the websites provide learning resources for both onsite and online visitors (Category #3).

Table 2.3 Website content analysis (n=896) based on a survey instrument with four categories and the total count for each category.

Description	**Cat. 1**	**Cat. 2**	**Cat. 3**	**Cat. 4**
Basic information (hours of operation, locations)	X	X	X	X
Onsite programs for visitors and educators*		X	X	X
Online educational resources			X	X
Interactive learning resources				X
Total Count	103	632	145	16

**Include pre-visit and post-visit resources*

Only 2% of the reviewed websites offer interactive learning resources (Category #4). The majority of Category #4 entries are considered large museums based on their annual operating budgets. The budget information for university-based museums (U) is not listed and is not readily available on the university websites. Nearly 90% of the Category #4 museums offer the click-and-learn (C) type of resources (Table 2.4).

Table 2.4 The list of 16 Category #4 museums. "Resource" is either click-and-learn (C) or game-based (G). "Size" was determined by a museum's operating budget as large (L), medium (M) or small (S). Budget information for university-based museums (U) was not available.

Institution	Region	Resource	Size
Bernice P. Bishop Museum	West	C	L
Burke Museum of Natural History & Culture		C	M
The Whale Museum		C	S
Idaho Museum of Natural History (Idaho State University)		C	U
Exploratorium		C	L
Jet Propulsion Lab (California Institute of Technology)		C	L
Lawrence Hall of Science (University of California, Berkeley)		C, G	U
University of Kansas Natural History Museum	Mt. Plains	G	U
South Dakota Mines Museum of Geology (South Dakota School of Mines and Technology)		C	U
Alder Planetarium & Astronomy Museum	Midwest	C	L
The Field Museum		C	L
Arts and Science Center for Southeast Arkansas	Southeast	C	S
American Museum of Natural History	Mid-Atlantic	C	L
Koshland Science Museum (National Academy of Sciences)		C	L
National Air and Space Museum		C	L
The Smithsonian Learning Lab		C	L

Based on the raw data, Category #4 museums have the highest mean operating budget at about $79 million dollars, followed by Category #3 at $6 million dollars and Category #2 at $2.7

million dollars. An initial analysis of variance (ANOVA) revealed that residuals of the raw data are highly skewed to the right. To make patterns in the data more interpretable, I performed the log transformation on the raw data. Subsequent ANOVA analysis showed the distribution of residuals as approximately normal. Importantly, there is a significant difference ($F_{1,28}$=8.38, p<0.005) between the mean operating budgets of museums in Categories #2, 3, and 4. Since the transformed data met the assumption of homogeneity of variances, I performed the Tukey's significant difference (HSD) post hoc test. It turns out that mean operating budgets for Categories #2 an #4 differed significantly at the 0.95 confidence level. Category #3 was not significantly different from the other two categories (Figure 2.6).

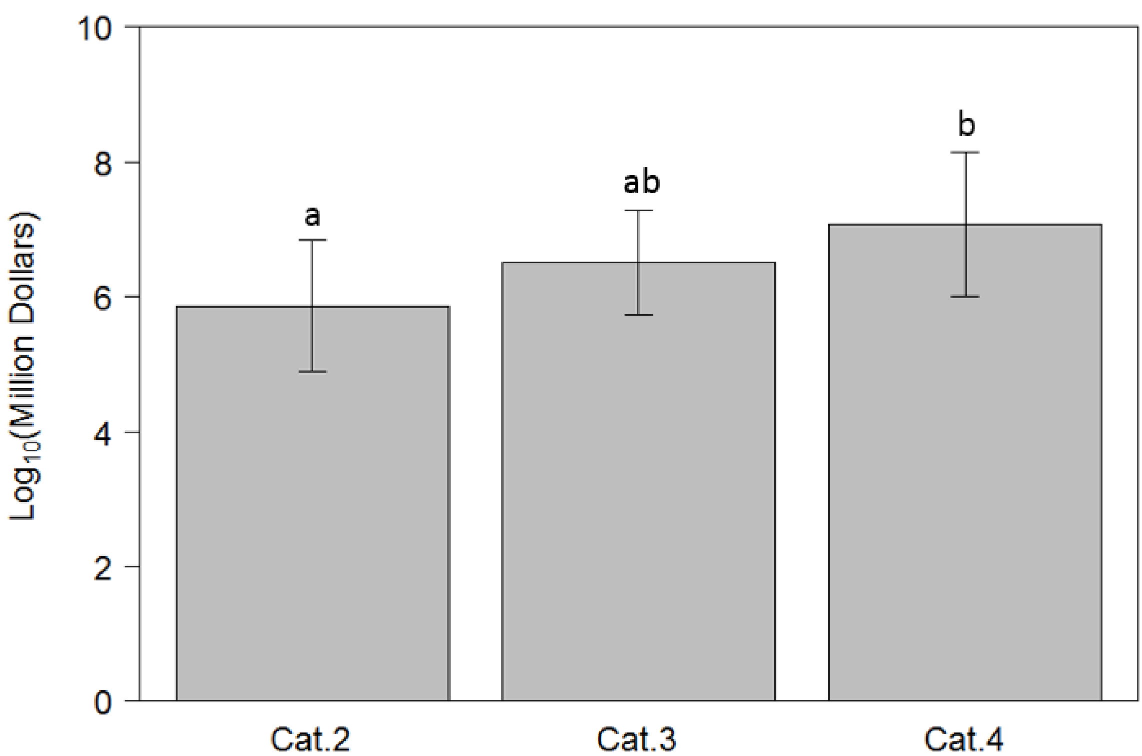

Figure 2.6 An analysis of variance (ANOVA) on the transformed data yielded significant variation among the mean operating budgets ($F_{1,28}$=8.38, p<0.005). A post hoc Tukey test showed that Categories #2 and 4 differed significantly at $p < .05$; Category #3 was not significantly different from the other two categories.

Discussion

Interactivity is key in engaging and educating museum visitors, and that is true for both online and onsite visitors. Interactive learning resources engage learners by allowing a certain degree of choice and control over the flow of information. Unfortunately, very little attention has been given to interactive learning resources on museum websites.

Based on this website content analysis, 70% of the reviewed natural history and science museums in the United States offer educational resources that support onsite activities and programs, but they offer little or no interactive learning resources on their websites. This suggests that most museums focus on their mission, which is to engage the local community with physical artifacts. This finding agrees with Apley et al. (2011) who reported that 65% of MFA grant applicants requested funding in the "Engaging Communities (Education, Exhibition, and Interpretation)" category.

These museums also use visually stunning Web design elements to advertise their onsite exhibits and programs. While people of all ages are increasingly glued to their devices, museums use their websites to motivate people who are still interested in the experience of self-discovery within the walls of cultural institutions. It is not just museums that must compete with a host of entertainment options that did not exist a generation ago; the rise of the digital age is also behind the steady decline of U.S. park visitation since 1988, after nearly 50 years of steady increase. For more than a decade now, most individuals prefer to stay indoors and watch movies, surf the Internet or play video games (Pergams & Zaradic, 2006).

Approximately 16% of the reviewed websites provide learning resources to both onsite and online visitors. These resources include DIY activities, worksheets, lesson plans as well as resources for distance learning and online citizen science projects. The number of museums in this category is likely to increase over the years for two reasons. First, the goal of many museums is to increase audience access to collections, by either digitizing non-digital content (e.g., audiotaped recordings, photographs, maps) or creating entirely new content. According to Apley et al. (2011), 24% of MFA grant applicants, mostly history and natural history museums, requested funding in the category of “Collections Stewardship (Management of Collections).”

Second, museums can reach out to a larger and diverse visitors by providing online learning opportunities. In 2014, the Metropolitan Museum of Art reported up to 29 million visitors to its website, compared to its six million onsite visitors (Giridharadas, 2014). In other words, out of these millions of individuals interacting with the museum online, only a small percentage would ever walk up the museum's famous steps. The first-ever study of diversity in American art museums highlighted the lack of diversity as a national problem (Levitt, 2015): “If museums don’t act now to fulfill a cultural contract that demands they serve audiences beyond their traditional patrons, their continued relevance into the 21st century will be seriously at risk—a view that is clearly gaining traction around the country.”

About 12% of the reviewed websites provide only basic information such as hours of operation and location either on a simple webpage or a Facebook page. I did not include museums that are listed only in business directories such as Yelp. The excluded museums may have an active social media presence other than Facebook, such as on YouTube or Twitter, but I did not attempt to locate them.

Needless to say, social media will remain the primary digital strategy for all museums, but especially for organizations that do not have the staff time or expertise to maintain web content. Although social media platforms are free to join and to use, it is no longer enough for museums to just post updates in this smartphone age. Instead, it is often necessary to integrate mobile technology, which is usually not free. In addition, social media give the public easy opportunities to air grievances, making it necessary for museum staff to dedicate time to address comments and concerns. In other words, social media presence requires constant tending, proper staff training, and management to make them effective, much like any other tools (Pew Research Center, 2013). Having said that, researchers who conduct studies on the role of social media in museums today may be especially interested in Category #1 museums that rely mainly on social media for their online presence.

Only 2% of the reviewed natural history museums and science centers offer interactive learning resources on their websites. This finding does not imply interactivity is not valued by the other museums; but rather, interactivity is likely incorporated into onsite exhibits, not online resources. According to Apley et al. (2011), natural history/anthropology museums used new technology to conduct mostly digitization/collections projects while science centers focused on programming and exhibitions (p.33). For many museums, adding interactive content to their websites is not a priority at the current stages of their digital adoption.

By comparison, art museums seem to give more emphasis to interactive resources than the other discipline groups. Arts Council England (2015) reported 25% of the 950 survey participants provided interactive resources, compared to only 2% of the 896 entries in this study. It is noteworthy to mention that Arts Council England (2015) relied on self-report survey data. Also, the authors did not specify if the "Educational Interactive Experiences" category used in their survey referred to both online and onsite activities. If both types of resources were counted by the UK survey participants, that would partially explain the big difference between the percentages reported in the UK study and this study.

Even though art museums focus more on interactive resources than museums in other discipline groups, Capriotti, Carretón & Castillo (2016) concluded that the top 100 art museums in the world have a low-level of interactivity (0.83 out of 3 points) on their websites. It appears that the top art museums around the world are still exploring effective ways to use interactive and immersive tools on their websites. In light of that, imagine how much more challenging it must have been for smaller organizations to implement similar digital strategies.

In spite of the small sample size for the ANOVA analysis, a significant difference between the mean operating budgets for Category #2 and Category #4 museums was detected. Based on the raw data, Category #4 museums have the highest mean operating budget at about $79 million dollars, followed by Category #3 at $6 million dollars and Category #2 at $2.7 million dollars. Unfortunately, budget information for many Category #1 museums was not available.

This website content analysis has several limitations. First, I did not review lengthy video resources even though some of them may be interactive. Second, some museums have elaborate designs so I might have missed the more creative navigation aids and did not locate the learning resources successfully. Third, some museums may have updated their websites since the summer of 2015 – either by adding or removing resources. Fourth, I may have overlooked duplicate entries. Due to the above reasons, the results should be viewed as "snapshot" estimates.

Based on this website analysis, well-funded large museums are more likely to provide interactive learning resources on their websites than small museums. As stated earlier, several reports (e.g., The MacArthur Foundation, 2011; The Pew Research Center, 2013; Arts Council England, 2015) have uncovered the prevailing barriers that prevent many informal learning organizations from expanding the range and quality of their digital resources as limitations in the areas of funding, staff time and expertise. Therefore, it is logical to assume that small museums are more profoundly affected by these barriers than large museums.

Even if funding opportunities are available, small to medium-sized institutions do not have the time to put together a major IMLS grant proposal. As a result, IMLS receives repeat applications from large institutions that tend to get approved. According to Apley et al. (2011), "Survey feedback suggests that the [grant] application process is more burdensome for small museums. Large museums often have dedicated grant writers and consequently may submit a greater number of applications (p.14)."

Unfortunately, not many efforts have been made to support small museums. In his investigative report, Kaplan (2016a) made it very clear that federal funds are not going to "small institutions with small budgets, which serve small-town residents who have less access to cultural institutions." This website content analysis revealed that nearly 900 natural history museums and science centers in the United States could do much more, if they had access to a practical strategy, to extend their educational roles in this digital age.

There are at least two reasons why Apley et al. (2011) reported a high rate of participation (54%) in online resources activities among the MFA-funded survey respondents (n=537). First, Apley et al, (2011) did not make a distinction between interactive and non-interactive resources, unlike this study and the survey conducted by Arts Council England (2015). More often than not, museum digital resources are not interactive but simply a digital representation of a physical entity. Second, Apley et al. (2011) included participants from all nine discipline groups. Interestingly, a combined 25% natural history museums and science centers reported using digital media to develop online learning resources in the survey by Apley et al. (2011), which is quite similar to the combined 18% of Categories #3 and #4 museums reported in this study.

One way to improve the survey instrument used in this study is to identify the museum size for all entries, not just Category #4 museums. By doing so, the growing divide between large and small museums would likely become very apparent. That could be accomplished when a more refined Museum Universe Data File becomes available. Before that, a basic question must be answered first, as discussed by Kaplan (2016b):

> What even is a museum? The numerous definitions are broad, encompassing everything from historical institutions to art museums to aquariums—included in this new figure [35,000], too, were supportive groups to other institutions. This makes them understandably tricky to count."

Another way to improve this study is to collect self-report survey data. Even with additional information, I am confident the survey pattern will remain consistent in the next few years – with the majority of museums in Categories #2 and #3.

Indeed, there has been much progress, but Clough (2013) urges museum educators to explore new ideas and approaches because much remains to be done. Even in the days before the widespread use of mobile devices, Marty (2008) reported that 49% of survey respondents (n=1215) expressed an interest in exploring online educational resources. Resonating with this, the Archives Libraries Museums (2016) shared that 50% of their survey respondents have seen an increase in visitor numbers to their websites and suggested that "the blend of online, social and in-person interaction is ideal to drive effective [visitor] engagement."

Chapter III: The Rationale for Interactive Learning Units on Museum Websites

A portion of this manuscript has been published:

Chong, C., & Smith, D. (2017). Interactive Learning Units on Museum Websites. *Journal of Museum Education*, 42(2), 169-178.

Interactivity is key in engaging and educating museum visitors, and that is true for visitors to museum websites as well as visitors to physical exhibits. Based on a recent website content analysis of nearly 900 natural history museums and science centers in the United States, only 2% of the reviewed museums provide interactive resources (see Chapter 2). The goal of this paper is to make the case for interactive learning resources on museum websites.

In his book, *Best of Both Worlds: Museums, Libraries, and Archives in the Digital Age*, G. Wayne Clough (2013) offers an optimistic outlook for museums: “In fact, the digital revolution offers museums, archives, and libraries a golden age of opportunity, because they are ideally suited for a world in which learning is informal and centered on inspiration and self-motivation” (p.2). Fortunately, there are many options for museums: video production, online databases, live streaming, virtual exhibits, and social media; but unfortunately, very little attention has been given to interactive learning resources on museum websites.

For several good reasons, most attention by museums has been given to social media (e.g., Russo et al., 2009; Kidd, 2011; Fletcher & Lee, 2012; Padilla-Meléndez & del Águila-Obra, 2013), including the production of YouTube videos (Greenfield, 2008; Robbins, 2015). In comparison with the development of an institutional website, maintaining a presence on social media (SM) does not require fewer technical skills and less funding; therefore, SM appears to be ideal for small to medium-sized organizations (Waters and Feneley, 2013).

Even as SM appears to be a “must-have” digital strategy for non-profit organizations, SM has yet to attain the “miracle cure” status. In cases where museum staff use creative ways to engage visitors on SM, such efforts did not generate a high-level of visitor participation (Lazzeretti et al., 2015). In addition, not all museum staff have the enthusiasm to act as SM “champions” (Proctor, 2010) and those who are interested in SM may face constraints in time and knowledge (Fletcher and Lee, 2012).

With the popularity of video content, one practical solution appears to be posting YouTube videos. Robbins (2015) reminds museum educators to set clear goals before proceeding:

> If a museum’s video-production motivations do not align with the types of content that are likely to succeed on YouTube, it may be more efficient and practical to publish only on platforms that are more suitable. If strong performance on YouTube is a goal, museums should be aware of the nuances, culture, and tropes of YouTube as a publishing platform, and mold their videos to suit YouTube’s environment and audience.

There is no doubt that video learning will continue to play a major role in education. Just watching a video, however, does not necessarily lead to learning (Stigler, Geller & Givvin, 2015). That is why video-based learning has gradually advanced from passive linear broadcasting to a more interactive experience for learners in recent years (Delen, Liew & Willson, 2014). In light of that, video production for small museums may require more technical skills and time than generally expected.

The fact that SM cannot be considered a one-size-fits-all solution opens the door for educators to explore new ideas and approaches using new digital media. Unlike other museum studies (e.g., Pallas & Economides, 2008; Lin et al., 2012; Lopatovska, 2015), the focus of this study is on interactive learning resources, not the overall website design.

Digital Learning, Interactivity, and Learning Units

First and foremost, it is important to understand a few key terms: digital learning, interactivity, and learning units. At its most basic, digital learning is simply learning with digital devices such as desktop computers, laptops, tablets, and smartphones. Digital learning may or may not require an Internet connection (online learning) and onsite presence (distance or virtual learning). In effect, digital learning can be as simple as reading an e-book, browsing the Internet, or listening to a podcast (Alliance for Excellent Education, n.d.).

Interestingly, what makes digital learning appealing is not just the devices used but rather the interaction opportunities the devices supply. Some digital resources engage the learner by allowing a certain degree of choice and control over the flow of information. These features are commonly known as interactivity in multimedia learning because it involves the interaction with computers or other digital devices (Betrancourt, 2005). Having said that, there has not been a consensus on what the term “interactivity” means (Waters & Feneley, 2013). The term “multimedia” is described as the presentation of information with a combination of both words (printed or spoken) and pictures (static or animated) by Clark and Mayer (2016). More often than not, digital learning involves multimedia learning.

However, the terms interactivity and multimedia are not interchangeable because multimedia content can be interactive or non-interactive. Specifically, interactivity is represented by the reciprocal interaction between the learner and the information mediated through a multimedia learning environment (Domagk, Schwartz & Plass, 2010), which can be illustrated by an example of student-content interaction.

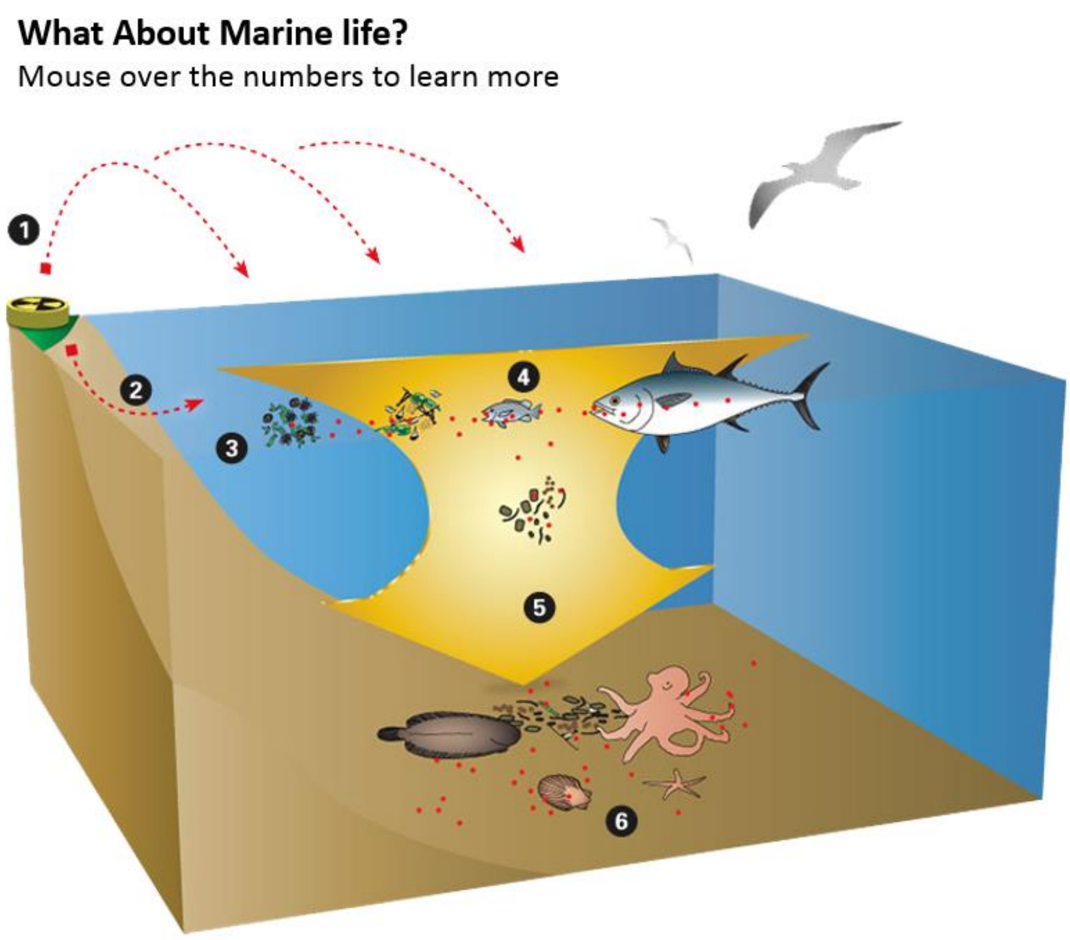

Figure 3.1 An interactive learning unit retrieved from http://www.whoi.edu/visualWHOI/i-how-is-fukushimas-fallout-affecting-marine-life. Permission for use was obtained from Woods Hole Research Center.

While both a video and an interactive learning unit use some combination of words and pictures, only the latter presents the content based on the learner's actions. In the example shown in Figure 3.1, the text is only revealed when the learner is ready to mouse over a number. This gives the learner the option of either going in chronological order (1, 2, 3…) or, if the learner is curious about one of the images that are paired with a number, they may start there instead. In contrast, the presenter in a video will explain the same set of images in a sequential sequence. For that reason, videos and typical webinars are not considered interactive, and neither are static Web pages.

In online courses, student-student and student-instructor interactions are also important (Moore, 1989). Importantly, research has found that student-content interaction is a strong predictor of student satisfaction in online courses (reviewed by Croxton, 2014). By transference, student-content interactivity is expected to play an even more important role in self-directed digital learning since the other two forms of interactivity are usually not involved.

In this dissertation, I used the term "learning units" instead of "lessons" because a complete lesson has the following components: learning objectives, an introduction, an activity, and a conclusion. In contrast, any educational resources can be referred to as learning units as long as each unit is adequate as a stand-alone piece. The most familiar format for learning units has the typical components of a complete lesson. When this format is used for informal learning, a learner benefits from the structure proven in a formal setting, but without the pressure of formal assessment. However, learning units can also be presented in other formats such as slideshows, and podcasts. Potentially, numerous content pieces can stem from just one main idea, each catering to a different audience (e.g., younger learners may prefer slideshows and adult learners may opt for podcasts). Conveniently, learning units can be incorporated into a more comprehensive lesson or module.

A Closer Look: Interactivity in Digital Learning

With a clear definition of interactivity and digital learning in place, it is now possible to take a closer look at how these two concepts work together. Generally, interactivity in digital learning spaces can be divided into three categories: low, moderate, and high. The most basic form of interactivity offers the learner some control over the pace of learning (e.g., click the "next" button to advance the screen). Low-moderate interactivity is commonly found in supplementary classroom resources (http://www.hhmi.org/biointeractive/click-learn-collection), and may include self-assessment questions as well as clickable icons or menus. In contrast, high-level interactivity requires either real-time participation or complex interactivity in game-based learning. In many educational games designed for young learners (http://pbskids.org/) and adult citizen scientists (http://www.gamesforchange.org/play/), one must complete the challenges on one level before advancing to the next level. In simulation games, which are widely used in the training of healthcare and vocational professionals, learners get to apply their knowledge and skills through "learning by doing" in built-in scenarios (http://www.nobelprize.org/educational/).

Since high-level interactivity is considered cutting-edge in today's multimedia learning environments, researchers have often been motivated to show that highly interactive learning resources have clear learning advantages; but current empirical findings remain inconclusive. In his review, Scheiter (2014) pointed out the lack of instructional effectiveness of the more sophisticated forms of interactivity. In particular, high interactivity can distract learners from the content because additional attention is required to sort through the complex interactive elements, often in an unfamiliar learning environment (Rasch & Schnotz, 2009; Lowe & Schnotz, 2014).

In making decisions about the level of interactivity to include, it is important to remember the ideal level of interactivity—high, moderate, or low—depends on both the learners and the content. For instance, animations that are usually associated with moderate and high interactivity are considered particularly useful for novice learners because animations provide visualization of abstract ideas or dynamic phenomena that are not readily observable in real space and time scales (e.g., blood flow, plate tectonics) so abstract ideas do not have to be inferred.

It appears that whenever there is the possibility of information overload, low interactivity is preferred. In fact, low-level interactivity has always been accepted as beneficial to learning even if user control was minimal, such as deciding when to proceed to the next screen (Betrancourt, 2005). Therefore, it is best to think of animated graphics and static graphics as being about as comparable as apples and oranges: both come from the same general category, but they are useful in different ways (Castro-Alonso, Ayres & Pass, 2016). For advanced learners, static graphics can be as valuable as animations when accompanied with concise text that provides all the critical information (Berney & Beetrancourt, 2016). From a design standpoint, having an awareness of the appropriate interactivity level is essential to deliver the best digital learning experience.

Interactivity in learning units can also impact the amount of time a learner spends with the content. Interactive elements have been shown to allow learners more time in the learning process (Evans & Gibbons, 2007). This was also discussed by Betrancourt (2005):

> Not only does this simple control give learners time to integrate information before proceeding to the next frame, but it also segments the animation into relevant chunks. New information can be processed and integrated progressively in the mental model... [Learners] can monitor the cognitive resources (e.g., attention and processing) they allocate to each part of the animation (p.291-294).

When shown the image in Figure 3 without the text, the learner has the opportunity to reflect on his/her own knowledge of this topic with questions such as "What do I know about this?" before making decisions about when to receive the information (e.g., to mouse over a number). After the text is revealed, the learner can then compare his/her prior knowledge with the new information with more self-reflection: "That's exactly what I thought!" or "I didn't know that!" In this manner, the pace of learning is determined by the learner, not the presenter and so, the learner can spend more time on the difficult parts of a learning unit.

Why Interactive Learning Units on Museum Websites?

In recent years, museum educators have continued to explore strategies that can advance the use of digital resources and tools in the classroom, largely in response to the on-going digital revolution. A total of six case studies are presented in a special issue of the *Journal of Museum Education* that "examines the current state of online learning offered by museums and discusses the pedagogy and practice in museum online learning" (Kraybill, 2015). As highlighted by Moore (2015), reports such as *TrendsWatch*, an annual publication produced by the American Alliance of Museums' Center for the Future of Museums, further urged museum educators to:

> Embrace change to leverage the potential of ongoing innovation in the tech sector, take calculated risks as promising new tools and approaches emerge, and adopt a learning stance to propel their work forward through an ongoing process of application, reflection, and refinement (p.145).

Though many of the benefits of digital learning seem self-evident, it is important to have a clear understanding of why interactivity should be included on museum websites so that one can make informed design decisions. *The NMC Horizon Report Museum Edition* by Freeman (2016) describes digital strategies as "more than the development of a website; they should include the multiple channels of technologies that provide unique opportunities for audience engagement" (p.22). As a digital strategy, interactive learning units can add to the already impressive scope of learning experiences provided by museums in at least four ways.

To add to museum online offerings

In his seminal book, *Making Museums Matter*, Stephen Weil (2002) stressed that "Museums matter only to the extent that they are perceived to provide communities they serve with something of value beyond their mere existence" (p.4). While digital innovations offer museums new opportunities for audience engagement, technology has paradoxically challenged museums to bring discovery and learning to new heights. Crow and Din (2010) express this sentiment by reminding museum educators that "museum visitors have now come to expect an array of online offerings from museums, just as they have come to expect online offerings in other aspects of their daily lives" (p.161). The Archives Libraries Museums (2016) interviewed 71 museum professionals to explore how they link digital strategies to visitor engagement plans and reported the following:

> This digital transformation can take many forms, from enabling museum visitors to use smartphones or tablets throughout the site to enhance their experience, to digitizing the collection and making it available online, to engaging with people before or after their visits via online channels.

An important function of digital technology is to allow museums to connect with audiences not served today (Clough, 2013). In terms of the target audience for interactive learning resources, many museum educators would agree with the report by the Denver Art Museum (2012) that style is a more accurate way than age to define an audience: “When programs designed for young adults consistently attracted audiences older (and younger) than the target demographic, we realized that style rather than age is a more useful way to think about audiences” (p.11).

Digital learning appeals to individuals who are intrigued by technology. While these individuals are likely to be in their teens, 20s, and 30s, digital technology also plays a prominent role in the lifelong learning of individuals outside of these age groups. It is therefore logical to assume that interactive learning units can contribute to a museum’s digital presence by extending the reach of learning opportunities to existing audience (engagement) and to reach out to new target audiences (outreach) in different age groups, either as blended (online and onsite) or stand-alone learning experiences, thus reaching a broader audience with a broader purpose.

To connect informal and formal learning

The view of museums as educational powerhouses has been further strengthened by the finding that American adults are better informed about science than their international peers because informal learning settings are a vital part of the American cultural and educational landscape (Falk & Dierking, 2010). The strengths of informal science learning that are generally absent from classroom learning are also documented in a major report by the National Research Council (2009) entitled *Learning Science in Informal Environments*, which endorses designed spaces such as museums, science centers, zoos and so forth as venues that support informal science learning.

Given the recognition of informal learning, Ucko (2011) suggests innovative approaches that draw from both formal and informal learning to offer the maximum benefits to the learners and to greatly enhance the educational impact of museums. Clough (2013) predicts that an emphasis on informal learning by museums will give them more visibility in their communities. Garcia (2012) elaborates:

> That museums should serve school audiences is beyond question. Formal and informal educational environments — schools and museums — should serve as the yin and yang of learning in a healthy community… Now is the time for museums to fully embrace their educative potential, to become articulate about their public value, and to enter the national conversation about how children and adults learn.

Because digital media have become a primary source of information for many, they serve as excellent springboards for learning. *The NMC Horizon Report Higher Education Edition* (Johnson et al., 2016) states that "Effective digital strategies can be used in both formal and informal learning; what makes them interesting is that they transcend conventional ideas to create something that feels new, meaningful, and 21st century" (p.22). The emerging trend of blending informal and formal contents in the education sector provides the perfect backdrop for museums to expand the range and quality of their online offerings.

To motivate learning in bite-sized portions

With information becoming more accessible than ever, there is an on-going demand to weed through the "need to know" versus the "nice to know". One possible way of providing structure is to implement bite-sized concepts, a strategy advocated by Elizabeth Merritt, the founding director of the Center for the Future of Museums (Athitakis, n.d.).

The idea of sharing information in small chunks is both pedagogical and pragmatic: First, there is strong evidence that meaningful segmentation of content is needed for new information to be processed, mainly due to the limited capacity of the brain's working memory (WM). The chunk concept was put forward by Miller (1956) when he proposed that most adults can generally store up to 7 (±2) information elements in the working memory. Cowan (2010) reviewed the literature and concluded that researchers tend to assume a smaller capacity of closer to 4, but essentially, the capacity limits are highly task-specific (i.e., compare and contrast vs recall).

In a recent review article, Paas & Ayres (2014) summarized the importance of WM and long-term memory (LTM) in human learning, which is the basis for the **Cognitive Load Theory (CLT),** first described by Sweller (1988). When dealing with novel information, CLT suggests a WM capacity of 4±1 elements of information and a duration of about 30s. However, the limitations of WM disappear for more knowledgeable learners when dealing with previously learned information stored in LTM. Apparently, LTM contains domain specific structures or schema that are used by the brain to store and organize knowledge by incorporating multiple elements of information into a single element with a specific function (e.g., driving a vehicle).

When information is successfully processed in the WM and integrated into existing schema in the LTM, learning occurs. By presenting information in manageable chunks, educators help learners organize the new information for WM processing, followed by LTM storage. This is especially critical for novice learners because they do not have a pre-existing schema in LTM with which the new information can be quickly integrated.

The small capacity of WM presents a big challenge for content designers – if a learner's WM is full, the excess information is simply lost. As said, the chunk concept is especially important for a novice learner because more mental activity is required to process new information. That is why short segments are always better than a continuous unit, as explained by Clark and Mayer (2016):

> Therefore, instructional methods that overload working memory make learning more difficult. The burden imposed on working memory in the form of information that must be held plus information that must be processed is referred to as *cognitive load*… Lessons should apply cognitive load reduction techniques, especially when learners are novices to the new knowledge and skills (p.41).

Second, the condensed content of bite-size learning units may motivate people to investigate topics that they would otherwise not investigate simply because the task seems more manageable. Bite-size learning is particularly suitable for young people, many of whom find reading blocks of text boring, as explained by Loranger & Nielsen (2013):

> Write for impatient users. Nothing deters younger audiences more than a cluttered screen full of text… Display content in small, meaningful chunks with plenty of white space. Small chunks help students retain information and pick up where they left off after the inevitable interruptions of text messages and phone calls… The best online experiences for teens are those that teach them something new or keep them focused on a goal.

In the context of museum learning, a survey by the Smithsonian Institution (2007) found that motivation in the younger museum audience is only loosely connected to the subject matter but instead closely linked to learning, connecting, and experiencing in a broad sense. In other words, it is the style of an activity that promotes learning outside of the classroom, not necessarily the learner's knowledge or specific interest in a subject matter. By extension, we can expect well-designed bite-size learning units to appeal to young learners, regardless of the content.

With that said, there is no strict rule on what constitutes a bite-size portion because the decision is topic dependent. Typically, one bite-size learning unit answers one specific question (e.g., what is an example that shows how X is related to Y). The same content is usually found in one section or even one paragraph in a chapter of a book. Learning units that are centered on one major theme are usually numbered and organized in a module because just as visitors to a physical museum appreciate a mix of structure and freedom, online museum visitors are also likely to prefer a similar mix of independence and guidance.

To repurpose content

Crow and Din (2010) suggested that "as your museum expands the digital resources that are available to the public, consider how these resources could connect with an online learning experience." Clough (2013) agrees: "The use of digital technology has to be focused on education and learning, some of which should be structured and purpose-driven, and some of which should be open-ended and curiosity-driven (p.31).

For many museums, the repurposing of content will likely start with the addition of multimedia content, such as videos and images, to existing print resources. In fact, teachers now prefer multimedia resources that can be pieced together in different ways for different classes rather than fixed lesson plans (Clough, 2013). Figure 3.2 shows an example of how content from the Evolving Idaho exhibit at Idaho Museum of Natural History was converted to an interactive digital learning content.

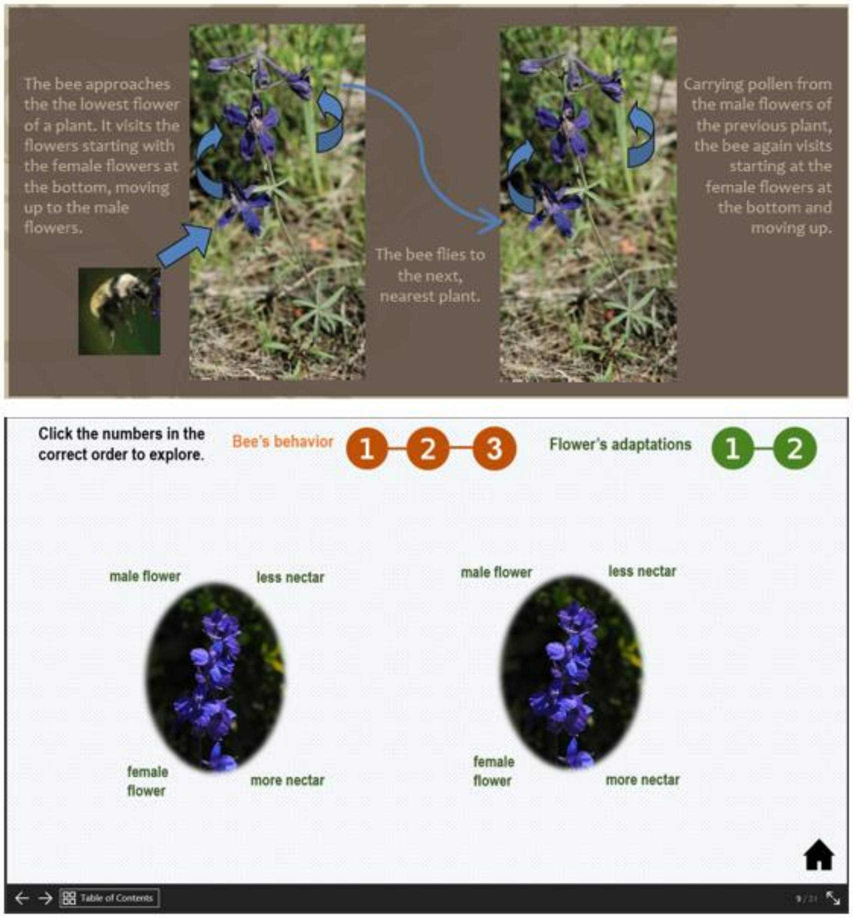

Figure 3.2 An example of how interactivity (below) was added to the content from the Evolving Idaho exhibit at Idaho Museum of Natural History (above).

In line with this approach is the on-going digitization of museum objects such as artifacts, fossils, and artwork. If every museum object has a story to tell, then many interactive learning units can be potentially generated from each museum collection. The same strategy can be applied to the objects in popular museum traveling or teaching trunks. Apley at al. (2011) reported that nearly three-quarters of the survey respondents (n=537) have already converted non-digital content (e.g., audiotaped recordings, photographs) to digital content, and seventy percent of them have already digitized collections materials (photographs, textiles, maps, etc.).

One way for museums to attract young people's attention is to encourage young people to use museum images as they blend genres and incorporate old ideas with new. According to Weber & Mitchell (2008), young people often "take up or consume popular images, and combine, critique, adapt, or incorporate them into their own media productions." This approach is also more inviting than simply referring visitors to an online museum collection that has hundreds, if not thousands, of items.

By tapping into both the underutilized and widely used resources, every museum can create unique interactive resources by harnessing the assets, and interests of the local community, which is in line with the recommendations by the National Research Council (2009) on informal science learning: "When possible, such exhibits and environments should be rooted in scientific problems, ideas, and activities that are meaningful to these local communities." Since possibly 60% of the 35,000 museums in this country are located in small towns (Ingraham, 2014), the emphasis on local relevance can showcase the passions that uniquely define each individual small museum.

Conclusion

This article is by no means exhaustive, however, the four reasons presented here serve as the basis for museums to offer interactive learning resources on their websites: adding to museum online offerings, connecting formal and informal learning, motivating learning in bite-sized portions, and repurposing content. To do so, it is necessary to first identify the characteristics of a digital learning platform that can support the development of interactive learning resources, especially for small museums. The next step does not involve any high-end technology but rather familiar devices and software that can be adopted for learning in a digital culture dominated by the brief and transient. In doing so, I hope to offer practical insights to support other organizations in their own digital innovation.

Chapter IV: The Characteristics of a Practical Museum Digital Learning Platform

As museums explore digital strategies to engage online visitors, an increasing number choose to publish content on their websites. Until recently, only well-funded museums had the resources to recruit a team of professionals to create in-house digital content. Today, the growing choices for online self-publishing tools presents museum educators with new opportunities to realize the educational and economic value of digital learning.

A recent website content analysis study revealed that nearly 900 natural history museums and science centers in the United States could do much more, if they had access to a practical strategy, to extend their educational roles in this digital age (see Chapter 2). With hundreds of publishing tools in the market, this article aims to provide a roadmap to help museum educators in the platform selection process.

A platform can be either a device or a software. In this study, a digital platform refers to a software that allows museum educators to publish interactive learning resources, which serve at least four important functions: adding to museum online offerings, connecting formal and informal learning, motivating learning in bite-sized portions and re-purposing content (see Chapter 3).

Content Authoring Tools and Digital Platforms

Even with limited or no technical skills, it is now possible for educators to produce high-quality multimedia digital content using **content authoring tools**, which are software applications with the capacity to combine and arrange media content. These tools include the familiar presentation software (e.g., PowerPoint®, Google Presentation®) and other more sophisticated tools (e.g., Articulate®, Elucidate®).

Digital platforms, which are widely used in higher education and increasingly used in the K-12 market and corporate training, are used for content delivery and progress tracking. Examples are Learning Management Systems (LMS) such as Blackboard and Moodle that deliver different content (e.g., links, videos, presentation software, and text) and assess learners' performance through learning analytics. With on-going upgrades, more content authoring tools are also serving as digital platforms while many digital platforms now offer built-in content-authoring tools (e.g., WordPress® and Blogger®). For that reason, the two terms are often interchangeable unless noted otherwise. Since both tools are Web-based, the content is hosted on the Web, making learning by connected individuals possible.

Another term widely associated with these tools is **e-Learning**, Legault (n.d.) defines it as "the use of electronic media (computer, tablets, or phones) to educate or train learners". Even though **e-Learning** and **digital learning** are nearly synonymous terms, the former refers mostly to self-directed learning related to formal training (e.g., Company A uses e-Learning for staff training) whereas the latter is more generic, referring to learning on a digital device, such as reading an e-book or watching a podcast.

There is little help available to guide museum educators in the selection of a digital platform because these tools are designed for e-Learning (e.g., corporate training) and online-hybrid courses (e.g., classroom learning). It is beyond the scope of this study to perform an exhaustive literature review spanning various disciplines. However, this article represents the first known attempt to pinpoint the characteristics of a practical digital learning platform for museums at the earlier stages of digital adoption. This approach is in line with the advice given by the Archives Libraries Museums (2016): "To determine the most cost-effective way to engage with the visitors and continuously evaluate which channel is the most effective" (p.5).

Figure 4.1 An infographic of the characteristics of a practical digital learning platform: usability, usefulness, and adaptability.

Overview

The term "practical" is used in this article to represent three possible functionalities of a digital learning platform: usability, usefulness, and adaptability (Figure 4.1). These recommendations are especially helpful for museums that use supplementary digital resources and are at the early or exploration stages of digital adoption. For these museums, there are many content types to choose from, ranging from slideshows to podcasts. Therefore, museum digital learning does not have to be about the latest technologies; rather, it is about content delivery on a *practical* digital learning platform.

To put it simply, usability is ease of use. At the minimum, a digital learning platform allows museums to overcome their top three barriers in digital adoption: limitations in the areas of funding, staff expertise, and staff time (Arts Council England, 2015; The MacArthur Foundation, 2011; The Pew Research Center, 2013). Such a platform has the essential features of being budget-friendly, requires only a gentle learning curve, and comes with an easy editing approach.

The usefulness of a practical platform in supporting learning is associated with choices available for educators to design learning experiences based on the science of learning. The three supporting features are learning assessment choices, learning analytics, and design choices. When utilized properly, these features add value to learning by providing prompt feedback to learners as they explore multimedia content designed to align with our capacity to learn. By having access to learner data, educators can then improve the content accordingly.

The adaptability of a practical platform allows museums to incorporate technology-enabled learning trends into the learning experience. The three enhanced features are cross-platform compatibility, embeddable Webpages, and social media. By using such a platform, the museum can reach out to a wider online audience by adapting to the current trajectory of learner digital learning habits and preferences.

Table 4.1 Rating matrix for the three characteristics of a practical digital learning platform: essential, supporting, and enhanced.

Essential	**Product 1**	**Product 2**	**Product 3**	**Product 4**	**Product 5**
Budget friendly					
Gentle learning curve					
Easy editing approach					
Supporting	**Product 1**	**Product 2**	**Product 3**	**Product 4**	**Product 5**
Assessment choices					
Learning analytics					
Design choices					
Enhanced	**Product 1**	**Product 2**	**Product 3**	**Product 4**	**Product 5**
Compatibility					
Embeddable webpages					
Social media					
Rollup score					

Fortunately, the platform selection process for museums does not have to be as complex as that in the classroom, as detailed by Bates (2015). The first step is to identify a list of tools that are within the acceptable price range and thus eliminating those that are over the museum's budget. Then, assess potential candidates using a rating matrix against the characteristics of a practical museum digital learning platform, as shown in Table 4.1. Next, assign a numerical rating for each cell in the matrix (e.g., 0=none, 1=low, 2=medium, 3=high) to indicate the degree of implementation of that feature, enabling a rollup score for each tool.

This article does not contain a comprehensive survey of available tools on the market, nor does it contain a comparative rating or evaluation of products. Instead, the remaining sections of this article will discuss in considerable details these features in the order of importance: essential, supporting, and enhanced. In short, the essential features are the most important requirements that must be met and thus, constitute the basic features of a practical museum digital learning platform.

Essential Features

The first concept for "practical" in the context of this article is usability or capable of or suitable to being used, as represented by the essential features: budget-friendly, gentle learning curve, and fast editing approach. These features are essential because digital adoption is only possible if the top three barriers (i.e., limitations in the areas of funding, staff expertise, and staff time) are reduced. Therefore, the essential features should not be evaluated in isolation because a platform is only considered practical if it meets all the three high-level requirements.

Essential Feature #1: Budget-friendly

Commercial platforms offer a variety of pricing models and plans available to accommodate the needs of organizations at different stages of digital adoption. Educators can generate a list of products just by using a pricing guide. For instance, museums that just want to try out a project or two can choose the "Pay per project" or monthly subscription option for one author to explore a new authoring tool. When external funding becomes available, museums can take advantage of the "Limited Time Licensing" option that comes with unlimited authors and storage capacity, making it ideal for grant-supported projects. At the same time, organizations committed to long-term digital strategies may prefer to pay a one-time fee and get the most out of the platform (Pappas, 2015). There are also many free tools with the basic features (Pappas, 2012).

These are enticing options if educators can utilize the platform without the typical support services offered by paid platforms. More likely than not, museums do not explore the free options due to a lack of in-house confidence and staff time.

Essential Feature #2: Gentle Learning Curve

Even if a software comes with the right price tag, it may require a steeper learning curve. After identifying potential products based on pricing plans, the next step is to assess the learning curve, as determined by the existing in-house expertise and staff time. This can be done by taking advantage of free trial offers to decide if there is a good match between the software and current staff skills. During the free, no-obligation trial period, it becomes apparent quickly if the skill sets match the complexity of the tool. If it takes more hours to develop content with the same basic features on Platform A than Platform B, then the easier option is clearly the better choice.

If the educator is already familiar with a presentation software, a product with a similar interface will be much easier to learn. In this case, you build your slides in the presentation software, and then use the new product to add interactive elements. If the museum leadership has articulated a long-term digital strategy to expand the range and quality of digital learning resources, then it may be worth the investment to provide staff training in using a more complicated software. Regardless of the stage of digital adoption of a museum, the product should still reflect the level of the learning curve the museum staff can comfortably handle.

Essential Feature #3: Fast Editing Approach

For educators who have to juggle several projects, the ability to make quick changes to published contents is another important time-saving feature. Proofreading is absolutely necessary and time-consuming but when educators know that revisions, ranging from correcting spelling errors to adding new information, is fast and convenient, they will publish new content more regularly. The ease of making modifications without a tedious complete redesign makes it convenient to maintain an up-to-date content. Likewise, when educators can tweak or completely change the theme (e.g., the color palettes) at will and on a screen-by-screen basis, it is more likely for authors to try out different designs, which makes the design process more interesting.

In addition, newer commercial platforms depend solely on the Web for data processing and storage (i.e., cloud-based). It is very convenient when an individual with an access to the account through a Web browser can create, store, upload and edit content anytime and anyplace. Even better, the service providers are responsible for ensuring data security and resolving technical problems or glitches, which significantly reduce the development cost and time because in-house expertise is not required for system maintenance.

The fast editing approach also facilitates the repurposing of content, which is the best way to get the most mileage out of the time and effort spent on a single project. For example, resources designed for general learning can be used as the template for a more comprehensive lesson for advanced learners and vice versa, simply by adding or removing information. In this way, the same content can be easily repackaged for a different target audience with minor modifications, allowing educators to generate a wide range of resources in spite of time constraints.

Supporting Features

The second set of features are concerned with the production or operation of something useful, as represented by learning assessment choices, learning analytics, and design choices. Unless a learning platform can support what the research says about how people learn, it will not fully serve its intended purposes. Thus, supporting features help educators apply research-based principles to facilitate the learning experience.

Supporting Feature #1: Learning Assessment Choices

Learning assessment choices refer to the different ways educators assess student learning. What goes hand-in-hand with learning assessment is feedback, defined by Hattie & Timperley (2007) as "information provided by an agent…regarding aspects of one's performance or understanding (p.81). Stobart (2008) described feedback learning succinctly: "When it comes to assessment for learning, feedback is seen as the key to moving learning forward" (p.144).

Within the large body of research on feedback, I organized the major findings based on the learning environment, either traditional classroom or technology-based. As reviewed by Shute (2008), feedback learning is crucial to knowledge and skill acquisition as well as for motivating learning in the classroom. In fact, feedback learning research not only deals with achievement-oriented outcomes, but also motivational and metacognitive-oriented outcomes. Specifically, Harks et al. (2014) reported that learning from feedback can "support learners' feelings of competence, facilitate the development of motivation and interest."

The little research on feedback in the context of informal learning comes from educational games and citizen science. Based on a systematic review of empirical evidence of educational games, Connolly et al. (2012) concluded that: "The most frequently occurring outcomes and impacts were knowledge acquisition/content understanding and motivational outcomes." As of yet, there is no research that specifically addresses motivation in relation to citizen science games. However, research has been conducted in relation to other types of citizen science projects. Rotman et al. (2012) suggested that factors such as feedback affect continued participation because volunteers valued being recognized and appreciated for their contributions. It is not surprising that motivational benefits of feedback play an important role in informal learning, simply because learning is driven largely by intrinsic motivation, not grades. The motivation factor can, in turn, contribute to the satisfaction of the learner's basic need to feel competent, and further enhances his/her interest and confidence in lifelong learning (Paris, 1997).

Once museum educators are convinced that feedback learning is a core component of learning, the next step is to decide the type of assessment: before (diagnostic), during (formative), and after (summative) a learning experience. By testing the prior knowledge of learners before they begin the learning activity using a diagnostic assessment, the educator gains a better understanding of how he/she can revise the content to addresses the knowledge gap. In the classroom, educators use summative assessments to assess learning by documenting what students know and can do at the end of a learning period (Bennett, 2011).

Formative assessment can benefit both the instructor and the students. Bennett (2011) suggests that the primary purpose of formative assessment is to suggest ways to modify instruction. Shute (2008) defines formative assessment as "information communicated to the learner that is intended to modify his or her thinking or behavior for the purpose of improving learning" (p.154). By careful design, this form of assessment allows students and teachers to use evidence to adapt teaching and learning to meet immediate learning needs (Bennett, 2011).

Formative assessment is also related to the role of self-regulated learning, defined by Pintrich and Zusho (2002) as: "An active constructive process whereby learners set goals for their learning and monitor, regulate, and control their cognition, motivation, and behavior, guided and constrained by their goals and the contextual features of the environment" (p. 64). Formative assessment has been found to help students become self-regulated learners by allowing them to take control of their own learning (Nicol & Macfarlane-Dick, 2006). More often than not, an individual who is interested in informal learning is already a self-regulated learner. That is to say, the person who is interested in learning outside of the classroom is already assessing his/her own knowledge learning process independently, either by confirming or adding to and restructuring his/her existing knowledge structure (Boekaerts & Minnaert, 1999).

To design a digital informal learning environment that builds on self-regulated learning, two characteristics of item-specific feedback should be considered: timing and type. Immediate feedback (IF) is given immediately after an answer is submitted and delayed feedback (DF) is given at a later time such as the completion of a block of content. Whether immediate or delayed, feedback can be further differentiated based on its specificity, complexity, and length:

- Knowledge of results (KR) – low complexity (i.e., only states if the response is correct or incorrect).
- Knowledge of correct response (KCR) – moderate complexity (i.e., the correct response is revealed whenever the correct answer is given).
- Elaborated feedback (EF) – high complexity (i.e., provides an explanation).

An example of multiple-choice assessment choice with both IF and EF is shown in Figure 4.2. Whether learning takes place in the classroom (Shute, 2008) or online (Jaehnig and Miller, 2007), students tend to pay more attention to immediate than delayed feedback and they perceive KCR and EF as more useful for learning than KR. In particular, EF is particularly more effective than KR and KCR for higher order learning outcomes.

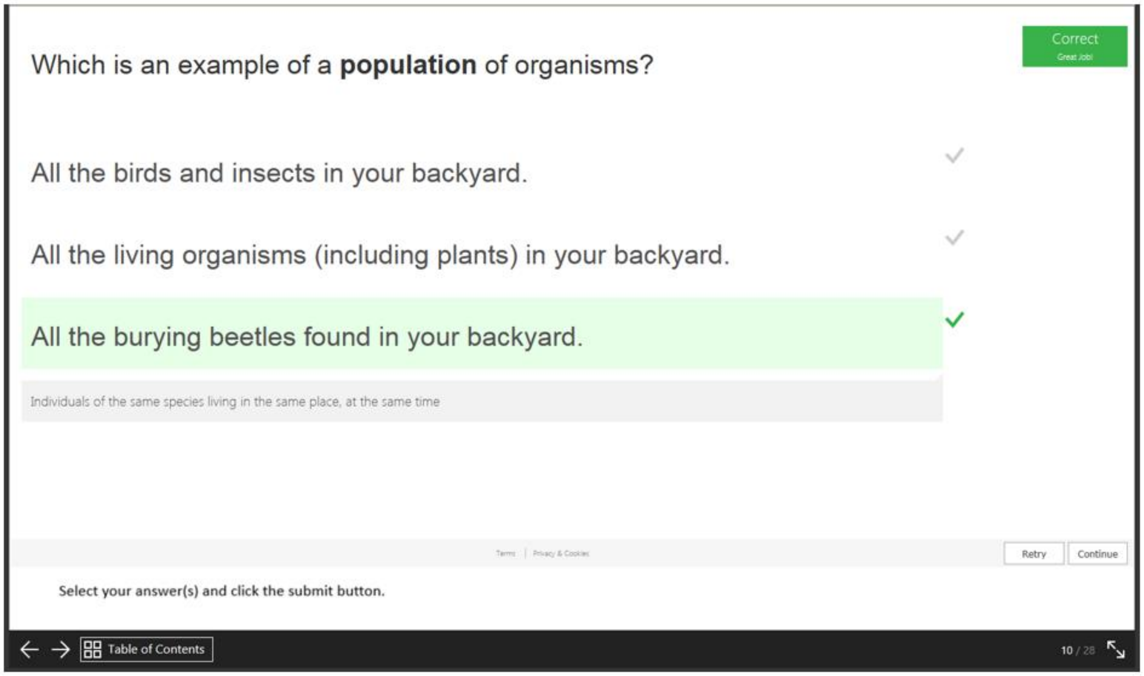

Figure 4.2 An Office Mix® multiple-choice assessment item with both immediate feedback (IF) and an optional elaborated feedback (EF).

Feedback learning can be explained using a model proposed by Bangert-Drowns et al. (1991) before the digital age but is still informative for recent studies. The model presents a five-stage cyclic process:

1. The learner in an initial state (e.g., prior knowledge and motivation).
2. A test item is presented and the learner activates his/her cognitive processes to retrieve information and search for the answer.
3. The learner responds to the item.
4. The learner uses the feedback provided to evaluate his/her response.
5. The learner makes adjustments to, for example, knowledge, beliefs, or strategies before the cycle starts over with a new adjusted initial state.

The frequency of formative assessment is another important factor. Classroom learning is more likely to be effective when learners are provided with frequent opportunities. For example, student response systems (SRS) are becoming increasingly popular in high school classrooms and university lecture halls. Hooker et al. (2016) reminded educators that frequent assessment opportunities must be accompanied by feedback: “Instructors need to give feedback soon after the assessment is given to encourage students to take control over their own learning.” That is why a major pedagogical strength of clicker use is the real-time feedback that offers a more accurate reflection of learning for both the instructor and the students (Reimer et al., 2015).

The science behind frequent formative assessment is related to the familiar saying, “Practice makes perfect”. Distributed practice is one of the ten learning techniques supported by a century-long of memory research (Dunlosky et al., 2013). Carpenter (2009) explained that distributed practice works because repeating retrieval processes regularly strengthens specific neuronal pathways, which facilitates subsequent access to the same information. This and other related findings are the basis for the book “Make it stick” by Brown, Roediger & McDaniel (2014). The authors suggest, among other things, frequent low stakes quizzes to improve student learning because this approach gives students many opportunities to identify misconceptions, reinforce concepts and ultimately gain a deeper understanding of the content.

One way to harness the benefits of frequent formative assessment in an online learning environment is to disperse assessment items throughout the learning activity. This approach favors self-monitoring because the five-stage model is potentially repeated whenever the learner encounters an assessment item during the learning process. Regardless of the frequency and type of feedback, learners must be willing to review the feedback (Timmers, Braber-Van Den Broek &

Van Den Berg, 2013). Even though the willingness to review feedback is not guaranteed, it can be promoted through digital learning in at least two ways.

First, the interactive nature of digital learning allows for potentially more mindful processing of each feedback, especially if each feedback is given immediately after an answer is submitted. With instant feedback, every student moves on knowing the correct answer. Since learners have control over the pace of learning, they can concentrate on a block of content before moving onto the next block. Better still, learners usually get multiple attempts on challenging items and so, they can take full advantage of self-paced learning – by learning without being influenced by the progress of other learners (Welsh & Dragusin, 2013).

Second, informal digital learning involves minimal cost in exposing one's uncertainty. In a traditional classroom setting, students who need help the most are usually the least likely to ask for help, possibly due to the fear of embarrassment, self-consciousness, and shyness. Fortunately, such factors do not come into play when learners receive computer-mediated feedback because nearly all the possible social factors related to the reluctance of seeking person-mediated are essentially non-existent (Aleven et al., 2006).

In the safe zone of self-paced learning, a frequent formative assessment with immediate KCR or EF feedback can promote what is known as "tolerance for uncertainty" associated with the uneasy realization of lacking knowledge. Over time, learners can potentially develop a mindset that welcomes new and even contradictory information. Not surprisingly, people who enjoy life-long learning tend to also have a high tolerance of uncertainty because they are curious about what they don't know well (Collins, 2009).

In the context of informal science education, an online formative assessment with feedback learning can potentially promote learning among individuals with weaker self-perceived skill sets or lower self-efficacy in science. Specifically, clicker-based technologies have been shown to increase success for underrepresented groups, including women in STEM, by offering all students a comfortable level of anonymity, thus providing equal access for students who may be reluctant to speak out in class (Reimer et al., 2015).

In terms of learning assessment choices, most commercial platforms offer multiple-choice, drag-and-drop, and short-answer. Even if these options are not available, it is still possible to generate the questions on another website and then embed the questions into a lesson. High-end learning platforms leverage the latest in cutting-edge learning science by offering adaptive or personalized learning technologies, which modify the content presented based on a learner's progress. In this manner, questions become more difficult if the learners respond correctly, and less challenging if the learners need more practice (Farrell & Rushby, 2016).

Supporting Feature #2: Learning Analytics

Closely related to learning assessment is learning analytics. The *NMC Horizon Report Higher Education Edition* (Johnson et al., 2016) describes learning analytics as: "An educational application of web analytics aimed at learner profiling, a process of gathering and analyzing details of individual student interactions in online learning activities " (p.38). An example of analytics information provided by Office Mix® is shown in Figure 4.3.

The widespread use of learning analytics in the education sector has led to the burgeoning research field known as Educational Data Mining (EDM), which is mainly concerned with collecting, storing, and analyzing the digital traces left by students in order to identify patterns of learning behavior for the purposes of improving and optimizing education practices. Ferguson (2012) identified the following key drivers for EDM and the associated questions:

- The growth in big data: How to extract value from big sets of learner data?
- The rise of online learning: How can we optimize opportunities for online learning?
- Political concerns for improvements in education: How can we optimize learning and educational results at national or international levels?

In a meta-analysis study, Papamitsiou & Economides (2014) listed six major EDM research goals: (1) student/student behavior modeling, (2) prediction of performance, (3) increase self-reflection and self-awareness, (4) prediction of dropout and retention, and (5) improve assessment and feedback services, a recommendation of resources.

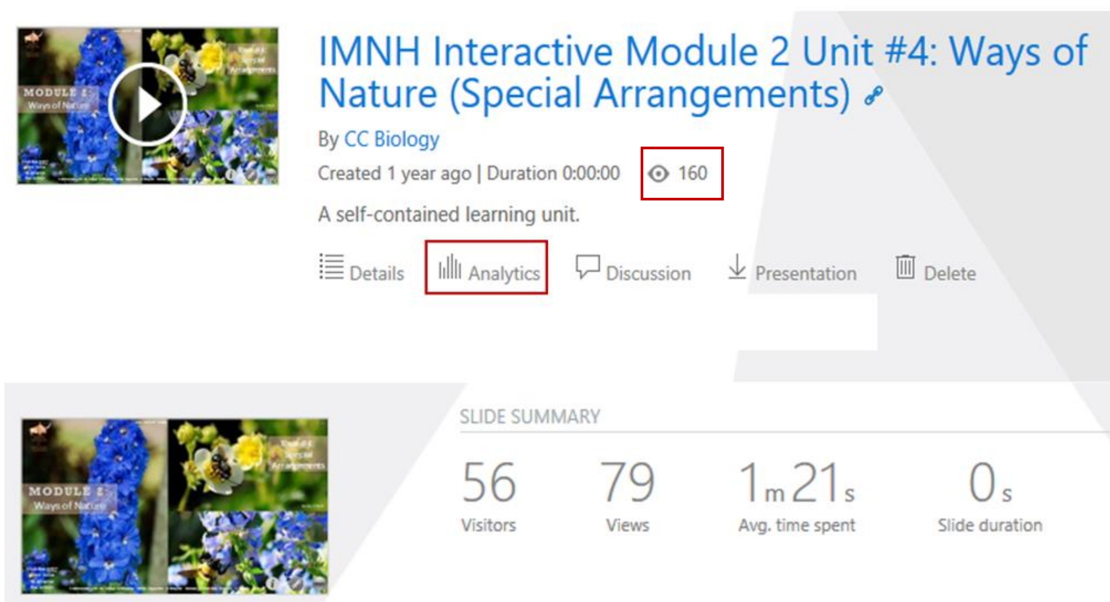

Figure 4.3 An example of analytics information provided by Office Mix®.

Needless to say, researchers have high hopes for learning analytics, not just to assist educators in creating a student-centered curriculum but also to assist students in becoming better learners, as envisioned by Tempelaar et al. (2013): “In this, learning analytics can play an important role: it provides a multitude of information that the student can use to adapt the personal learning environment as much as possible to the own strengths and weaknesses.”

But EDM brings even more to the table – some researchers want to use EDM as the basis for quantitative research on constructionist learning. Berland, Baker & Blikstein (2014) see the potential of using EDM to make rich inference about learning and learners: “Much of constructionist research is exploratory rather than confirmatory. This makes it an excellent fit for EDM when compared to traditional statistical methodologies.”

Even in the context of informal learning, it is crucial to have some insight on how learners respond to the content because such information reveals how the content can be improved and what design decisions should be introduced. Certain information gleaned from analytics can be particularly useful in the evaluation of the learning assessment. For example, if many learners gave the wrong answer to a certain question, the clarity of that question or answer choices likely need to be improved.

Although studies on informal learning are usually small-scale, there are new EDM tools that allow researchers to combine datasets and extract useful information (De Laat & Schreurs, 2013). Therefore, museum educators should collect learner data whenever possible because when combined with results from other studies, the data may have both short-term (content improvement) and long-term (general museum learning) implications.

Conveniently, most digital platforms come with built-in analytics that not only tracks data (e.g., learner location, and time spent, scores and answers to questions) but also generates reports. Unlike in classroom learning and corporate training, museums do not need detailed analysis of course performance by individual users. For museums, a digital learning platform with a basic analytical functionality may be adequate and possibly a better choice over a more pricey option with a host of criteria for comparing individual users.

Supporting Feature #3: Design Choices

The "easy-to-use" selling point of many content-authoring tools greatly appeals to non-technical authors because it implies minimal efforts when it comes to making design choices for the interface and the content. These design decisions are closely associated with User Experience (UX), the overall experience, and User Interface (UI), the appearance and layout (e.g., font types, color scheme) as well as the navigational elements (e.g., menus, buttons). Using the analogy of horse-riding, Miller (2012) explains that "UI is the saddle, the stirrups, and the reins; UX is the feeling you get being able to ride the horse and rope your cattle."

Fortunately, many authoring tools provide either a standard UI or a selection of themes based on the standard conventions. This makes it easier for the learners because those elements are commonly seen on the Web. Mangan (2016) makes the concept more manageable when making those design choices from scratch: "Good UX is a lot like a simple and predictable pizza, fresh out of a wood-fired oven with nothing but tomato sauce, mozzarella cheese, and basil." Thus, UI elements should be simple and consistent, not superfluous or overloaded.

Since most resources on design choices are written for professionals in related fields, educators can take advantage of resources provided by practitioners from other fields, such as the information available on the website of CDC Learning Connection (n.d.), where scientists and medical professionals share guidelines they use to engage public health and healthcare professionals through digital contents.

When it comes to multimedia learning, information is presented with a combination of both words (printed or spoken) and pictures (static or animated). Whenever possible, the design choices for multimedia content should follow the proven ways to minimize cognitive load that stresses the capacity of learner's working memory (Clark and Mayer, 2016). It is beyond the scope of this article to discuss the design principles in details but Figure 4.4 is an overview adapted from the version by Talbert (2014):

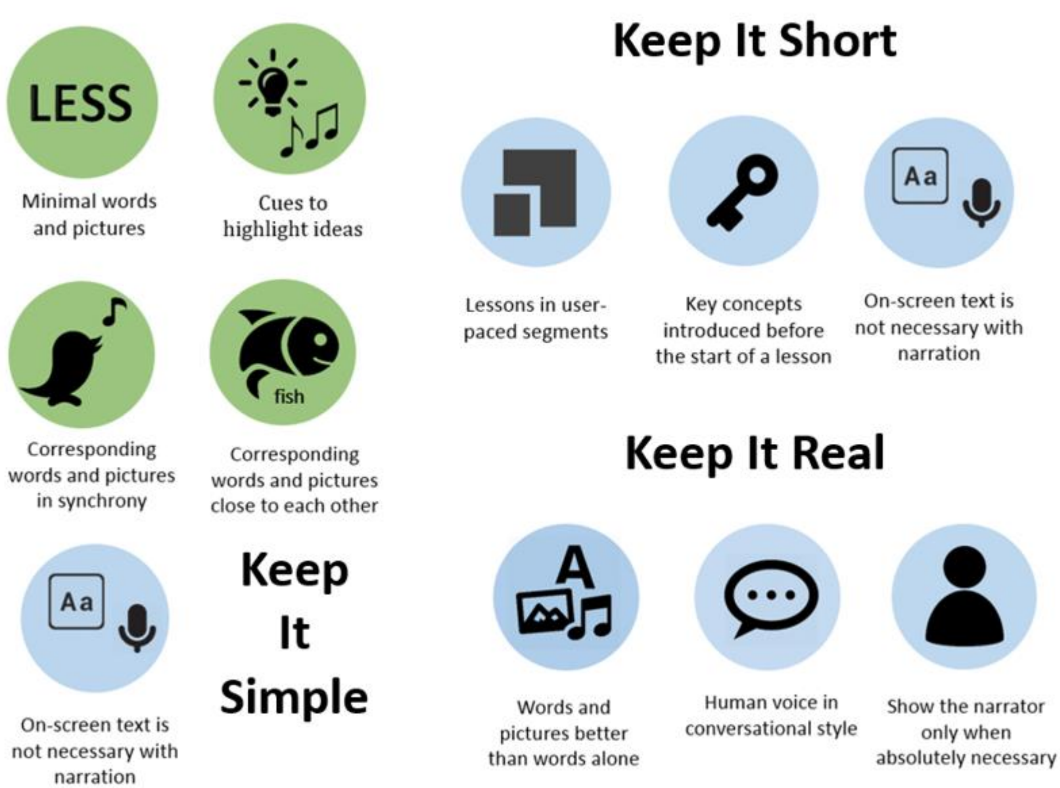

Figure 4.4 An overview of the major multimedia design principles.

One way educators can evaluate the design choices of a digital learning platform is by asking questions based on the design principles. Here are a couple of examples:

1. Can I decide the placement of text as well as images on each screen? (Figure 4.5)
2. Can I highlight important elements? (Figure 4.6)

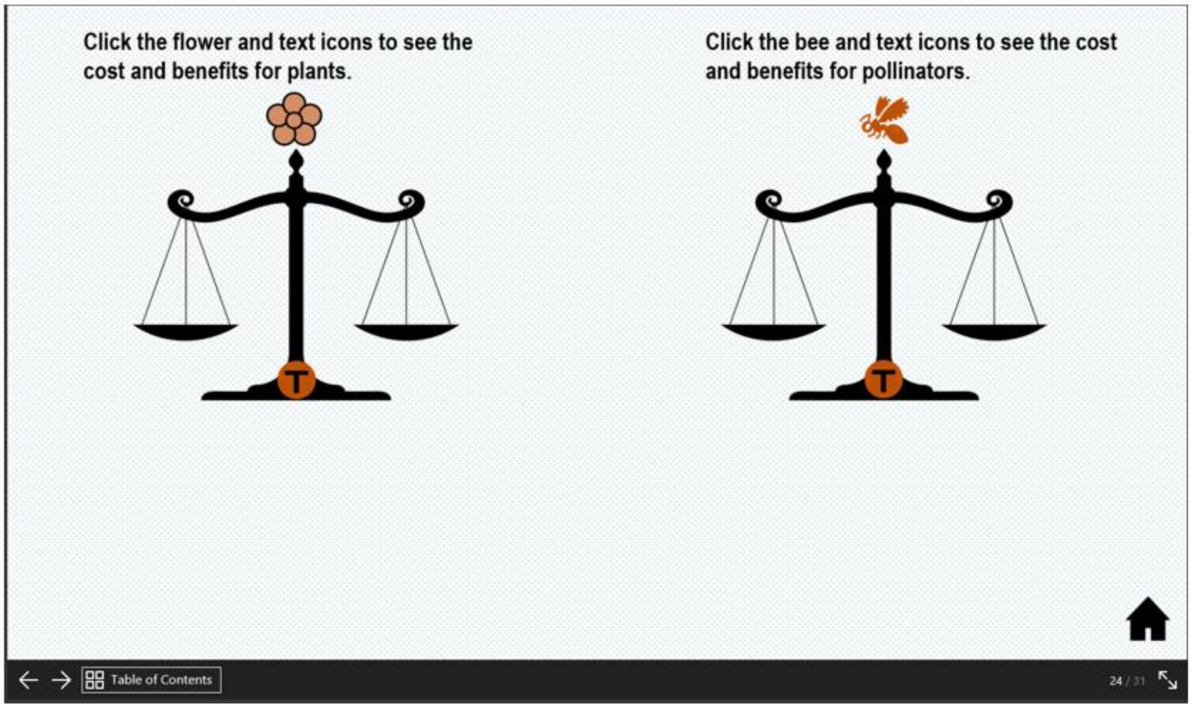

Figure 4.5 In Office Mix®, the author decides the placement of text and pictures.

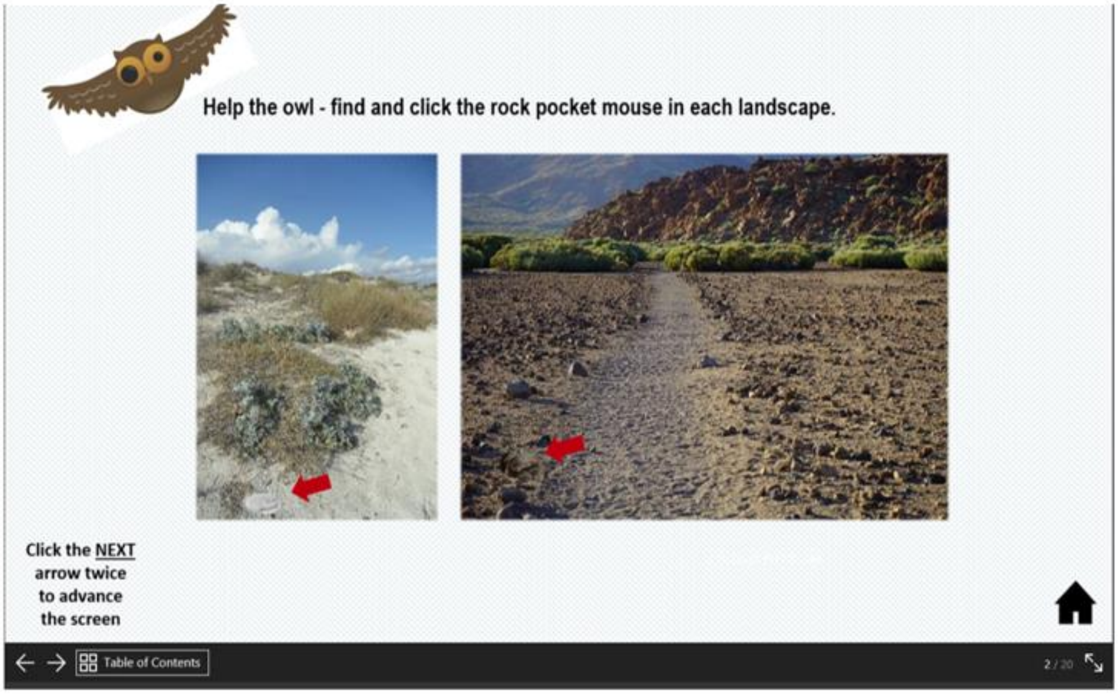

Figure 4.6 In Office Mix®, the author can use cues to highlight key elements.

Enhanced Features

A digital learning platform with enhanced features can adapt to the preferences of learners, as per their needs or likings. These features are cross-platform compatibility, embeddable Webpages, and social media. The main reason for choosing a digital platform with enhanced features is greater accessibility for learners and therefore, the possibility of reaching a wider audience. The following discussion is gleaned from online articles because this study is not concerned with institutional framework or solutions, which seem to be the primary research areas.

Enhanced Feature #1: Cross-Platform Compatibility

Any Web content that adjusts to the screen size it detects is considered responsive and compatible across different platforms. At the point of this writing, cross-platform compatibility is not a standard feature of digital platforms. For example, Moodle on different browsers like Firefox and Chrome have different formatting.

Driven largely by the massive use of mobile devices in nearly every aspect of our lives, the demand for responsive website design has permeated the education sector and the corporate world. However, the majority of digital contents remain optimized for desktop computers, and so, most people only expect the mobile format as a complement to the main desktop delivery format.

Since informal learning is all about self-directed learning, giving learners the choice to learn on their own terms and on their own devices may represent the pinnacle of user control. With the ability to cover selected chunks of information at a time, the task is far less imposing. Learning can take place literally anytime and anywhere because more likely than not, a learner will carry with him/her some type of digital device throughout the day.

Enhanced Feature #2: Embeddable Webpages

To put it in simple terms, to embed is to post an external webpage and place it in your content so viewers can view the webpage within the confines of your platform (Figure 4.7). At the same time, there is no need to import large files or obtain permissions to use these resources because the content is simply shared so the original websites can track the visits. This is done by copying and pasting the embedding code available on the original websites into the specific field in the authoring software. Due to the popularity of this form of content sharing, some content providers no longer provide embedding codes unless you go through an agent such as Embedly, which offers instant access to over 300 content providers for a fee (Rosa, 2016).

Having the ability to embed webpages is especially useful if the author wants to include external resources. In this manner, external contents can be shared extensively with little or no restrictions. Another advantage of having embedded webpages is that learners do not have to switch between different tabs during the learning activity, and thus, are less likely to get distracted and leave the original site.

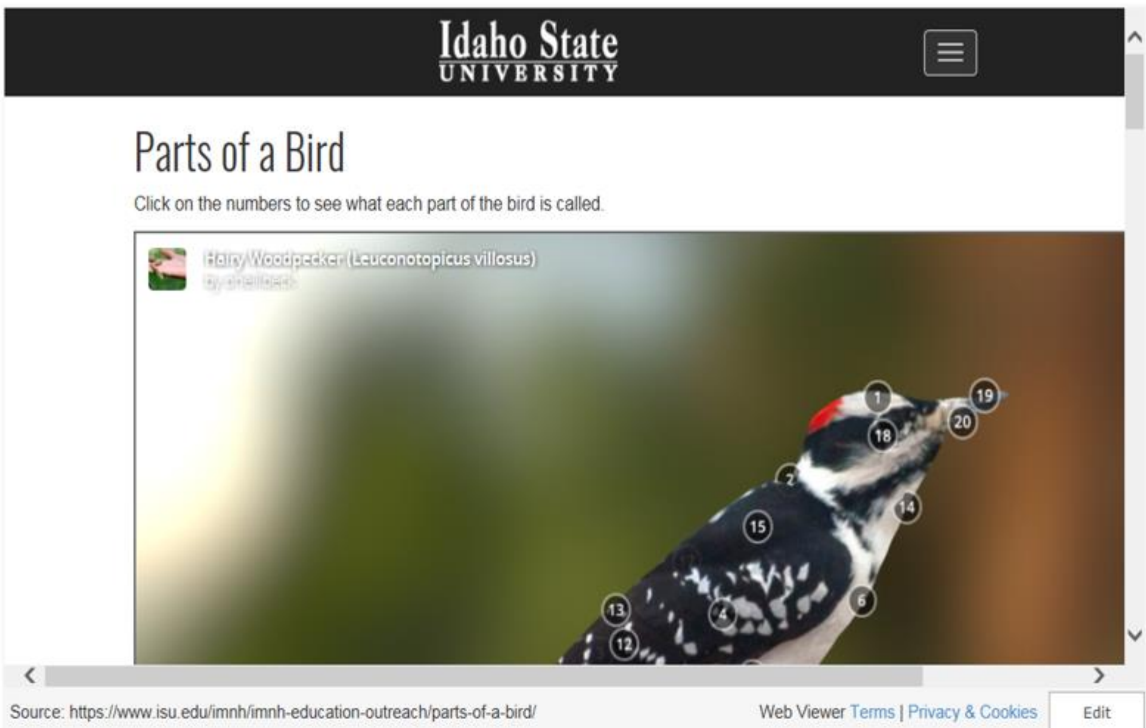

Figure 4.7 The Office Web Viewer allows live Webpages to be embedded.

Enhanced Feature #3: Social Media Sharing

No one can deny that social media has become almost second nature for many people. The sharing of opinions, views, comments, as well as resources on social media, is an everyday routine for many individuals as a way of building relationships with those who have similar interests, attitudes, values, and lifestyles. That is why more digital platforms have begun to allow content sharing on the major social media sites with a simple click. Given the rise and fall of social media sites are largely unpredictable, this feature appears to be only convenient for users who already have a steady group of followers.

Conclusion

Since there is currently no adequate theory for choosing a digital museum learning platform, this article provides a set of criteria that can help inform educators when making decisions about which platform to use. Indeed, museum educators may feel overwhelmed by all the factors that need to be taken into consideration during the selection process. With the plethora of choices available, our decisions will not always be perfect. That is why it is best to start with free tools or free trials at the exploration stage.

The essential features represent the minimal requirements of a digital learning platform. A budget-friendly platform can be identified by using a specific budget range to identify a list of potential candidates – the narrower the range, the shorter the list. In this study, I only wanted to explore tools that do not incur any additional cost to the museum. Next, I proceeded to narrow down the choices to software that support PowerPoint® so it would be a gentle learning curve for me. Then, I reviewed two products for their editing features by creating a few sample screens. At this point, it became apparent that one product offers more control in terms of editing privileges than another. But that in itself was not enough to finalize my selection. In spite of its limited design choices, I decided to use Office Mix® because it scored higher on the supporting features of learning assessment choices and learning analytics than PowerPoint® Online. For museums at the early stages of digital adoption, the enhanced features (cross-platform compatibility, embeddable Webpages, and social media) may not be of much importance. Likewise, these features were not determining factors in this study.

Chapter V: Office Mix® as a Practical Museum Digital Learning Platform

In response to the call by the American Alliance of Museums' Center for the Future of Museums to "embrace change to leverage the potential of ongoing innovation in the tech sector" (Moore, 2015, p.145), I used Office Mix®, a new and free add-on software to PowerPoint 2013, as a digital learning platform. By working with the Idaho Museum of Natural History (IMNH) and Idaho State University professors involved in the Evolving Idaho exhibit, I designed and developed a virtual exhibit and two modules with a total of eight learning units (see Appendix A).

This case study is divided into four main sections: the challenges, the opportunity, the approach, and the outcome. The bulk of this article focuses on the approach where I applied the A.D.D.I.E model (Analyze, Design, Develop, Implement, and Evaluate). I also incorporated research findings from two main domains of learning: cognitive (our capacity to learn) and affective (our motivation to learn) into the design and development process.

The Challenges

While there are at least four good reasons to include interactive learning units on museum websites: adding to museum online offerings, connecting formal and informal learning, motivating learning in bite-sized portions and repurposing content (see Chapter 3), there is very little research that can shed light on the design and development process, specifically for museums facing limitations in the areas of funding, staff time, and staff expertise. This article argues that it is possible to create interactives on museum websites with a reasonably modest effort.

First and foremost, any museum learning research must rely heavily on theories developed in non-museum contexts (Schwan et al., 2014). To counter for the paucity of resources, I compiled a succinct set of guidelines based on current research in the form of infographics so museum educators can quickly develop proficiency in online content creation without disrupting their other professional responsibilities. These infographics represent my interpretations as to how selected research findings from related disciplines can be applied to the design and development of interactives on museum websites.

The Opportunity

Like many cultural institutions, the Idaho Museum of Natural History (IMNH) views digital technology as essential to their creative output. A major digital undertaking at IMNH is the Idaho Virtualization Laboratory (IVL) that uses state-of-the-art technology for imaging, virtualization, and simulation of living organisms, landscapes, and material items. Like all museums, IMNH would prefer to have digital skills spread throughout their organization rather than concentrated in any one area. However, limitations in the areas of funding, staff time and staff expertise prevent IMNH from expanding the range of quality of their digital activities.

At the point of this writing, IMNH leadership has not articulated a digital strategy, but the small scale allows the museum to take risks without putting a lot on the line. The shorter lines of communication meant I worked directly with the museum education coordinator at that time, Ms. Becky O'Neill, who gave me full access to the museum website – making it an empowering experience that would perhaps not be possible at a larger institution.

Until the last decade, multimedia content development was the exclusive domain of a team of professionals. Typically, content provided by subject matter experts (SME) is given to individuals trained in instructional design (ID), who shape the content based on design and learning principles (e.g., Gagne's Nine Steps of Instruction, Cognitive Theory of Multimedia Learning) to maximize positive learning gains. These instructional decisions are then implemented by graphic designers and computer programmers, who are responsible for the technical aspects of the content (e.g., text, graphics, videos, audio, and animations). According to Frey & Sutton (2010), the availability of easy-to-use content-authoring tools has virtually eliminated the cost and technical expertise that formerly characterized multimedia content development and production. In short, it is now possible for the entire project to be managed by as few as one individual.

The Approach

When planning a new digital side project, museum educators need an easy-to-follow model to help them stay organized. Ideally, there should be a uniform approach since digital content has been widely used in the last two decades for staff training in businesses and government agencies (e-Learning). However, a quick search of the literature reveals that many design models (e.g., Multimedia Design Models, Instructional Design Models) have been proposed by various scholars.

For simplicity sake, I utilized the widely used A.D.D.I.E. model (Seels, and Glasgow, 1998) but borrowed ideas from models by Dick, Carey & Carey (2006) and Morrison, Ross & Kemp (2010). I modified the A.D.D.I.E. model by adding key components to the five steps that make up the acronym: analyze, design, develop, implement, and evaluate (Figure 5.1). In spite of the popularity of the A.D.D.I.E. model, it is not without drawbacks, the major one being the linear approach to the process (Frey and Sutton, 2010). Still, the five steps served as an easy-to-use organization tool to help educators think about all the tasks involved in the project and the complexity of each step, as determined by the key components.

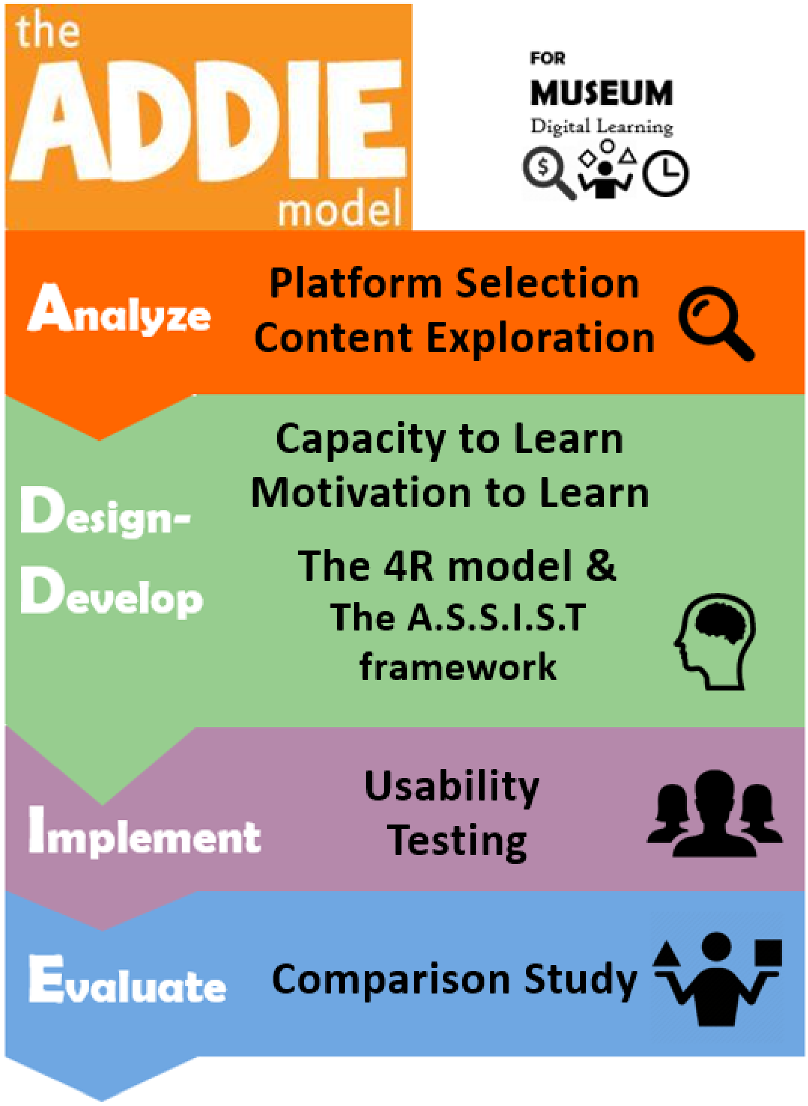

Figure 5.1 A modified A.D.D.I.E. model with key components added to guide educators in the design and development of interactive resources on museum websites.

Step #1: Analyze (Resource Planning)

The first step that comes before all projects is usually hatching a great plan. In this case, resource planning involves identifying the potential resources for a new digital project. This includes resources that the museum already has and those that still need to be acquired. Much like how this step is commonly included in proposal writing, museum educators review the necessary resource list and make plans on how to maximize the use of existing resources and where to acquire new resources.

Platform Selection. As discussed in Chapter 4, there is a long list of content authoring tools available for purchase or subscription. However, my goal was to make this idea happen without a budget. Because I am familiar with PowerPoint®, I promptly narrowed down the choices to PowerPoint Online® and Office Mix®. At first glance, both tools seem to be candidates for a practical museum digital learning platform (Figure 5.2).

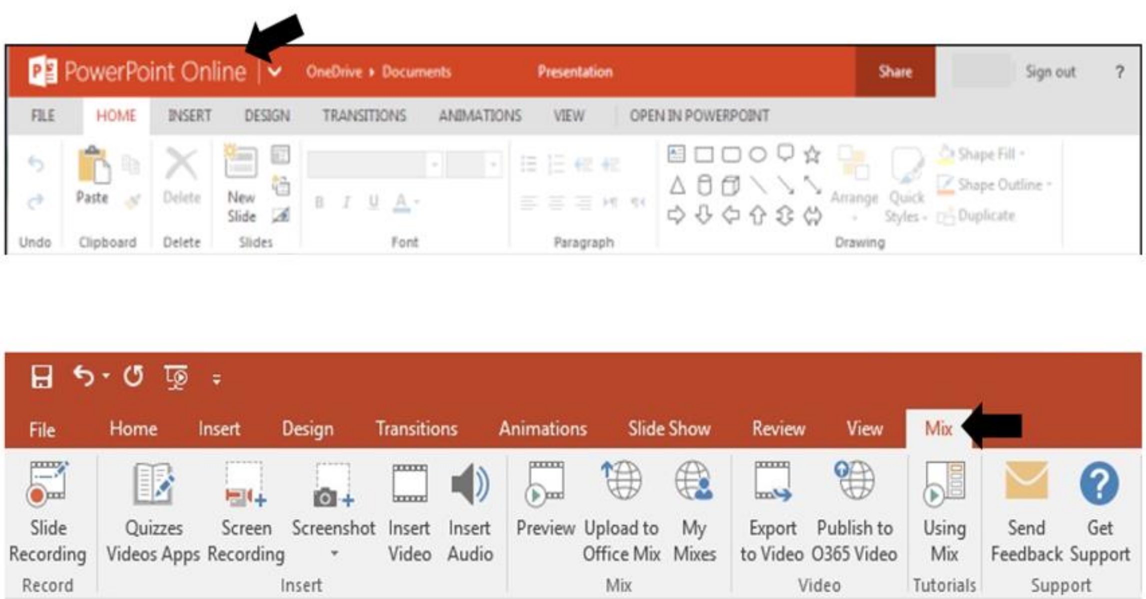

Figure 5.2 PowerPoint Online® (above) and Office Mix® offer a similar interface. Even though PowerPoint Online® has simplified applications, it offers better collaboration features than desktop-based PowerPoint®.

The first few attempts with PowerPoint Online® quickly revealed why this seemingly simple strategy has not been adopted elsewhere. PowerPoint Online® maybe ideal for collaboration but it does not serve well as a digital learning platform because most of the advanced features of PowerPoint® desktop version cannot be converted to the online version and anyone who has a link to a presentation also gets full editing privileges (Microsoft, n.d.). Having said that, Microsoft (2014) was clearly aware of the limitations inherent in PowerPoint Online® because they introduced Office Mix®:

> "We've heard from teachers that it can be difficult and expensive to make online lessons. Creating online lessons takes multiple pieces of expensive software, some of which are expensive or require serious technical skills, like complex video editing and timelines. All just to get a lesson online. Our goal is to make it easy to create an online lesson or presentation with something you already know how to use – PowerPoint. We call these online, interactive presentations "mixes" and the tool created to build them is Office Mix."

As discussed in Chapter 4, the characteristics of a practical digital learning platform for museums can be grouped into three categories: essential, supporting, and enhanced. I decided to use Office Mix® because the software fulfills the essential features of a practical museum digital platform (Table 5.1). There is little, if any, learning curve required for using Office Mix® if users are already familiar with the basic features of PowerPoint®. Here are the basic steps:

1. Download the software to a device that already has PowerPoint® 2013 or a later version installed and sign up for an account.
2. Prepare a typical PowerPoint® presentation or use any of the new add-on tools.
3. Click "Upload to Mix" on the Mix tab to upload the presentation to your personal gallery.

4. Click the "Share" icon beneath a presentation and copying the code (small, medium or large) to embed the content into any website.

To modify the content of a published mix:

1. Edit the original PowerPoint® presentation.
2. Choose "Upload it to mix" and then select the "Updating an existing mix" option.
3. Click the specific mix to replace in the list of your published mixes.
4. Set permissions to decide who can view a specific mix or mark it as private so only the author can see it. This feature is especially handy if the content needs to be reviewed by specific individuals before being made public.

Table 5.1 Evaluation of Office Mix® as a practical museum digital learning platform.

Characteristic	Feature	Low	Medium	High
Essential	Budget friendly			✓
	Gentle learning curve			✓
	Fast editing approach			✓
Supporting	Assessment choices		✓	
	Learning analytics		✓	
	Design choices	✓		
Enhanced	Cross-platform compatibility			✓
	Embeddable resources		✓	
	Social media			✓

Office Mix® serves as both a content authoring tool and a digital learning platform. All published mixes are stored in Microsoft's cloud service. This feature is by no means unique because other slide sharing websites also provide cloud storage. What makes Office Mix® more preferable is that interactive elements (e.g., quizzes and polls) can be maintained whereas slide sharing websites only support non-interactive files (e.g., videos, pdf documents).

Content Exploration. After a digital platform has been selected, there are at least three aspects related to the content that should be explored: content ideas, the style of learning, and the type of content (Figure 5.3). Generally, the content is designed to complement existing museum resources as suggested by Crow and Din (2012): "As your museum expands the digital resources that are available to the public, consider how these resources could connect with an online learning experience."

For many museums, the repurposing of content will likely start with the addition of multimedia content, such as videos and images, to existing resources used by teachers. In this way, teachers can have ready-to-use multimedia resources in the classroom instead of having to find ways to visually convey the information. In addition, teachers now prefer multimedia resources that can be pieced together in different ways for different classes rather than fixed lesson plans (Clough, 2013).

Unlike learning resources produced by textbook publishers, museum learning resources do not need to offer comprehensive coverage of a topic and therefore, can also be used to supplement classroom learning. The on-going digitization of museum objects, such as artifacts, fossils, and artwork, also offers a plethora of content ideas. If every museum object has a story to tell, then many interactive learning units can be potentially generated from each museum collection. The same strategy can be applied to the objects in popular museum traveling or teaching trunks.

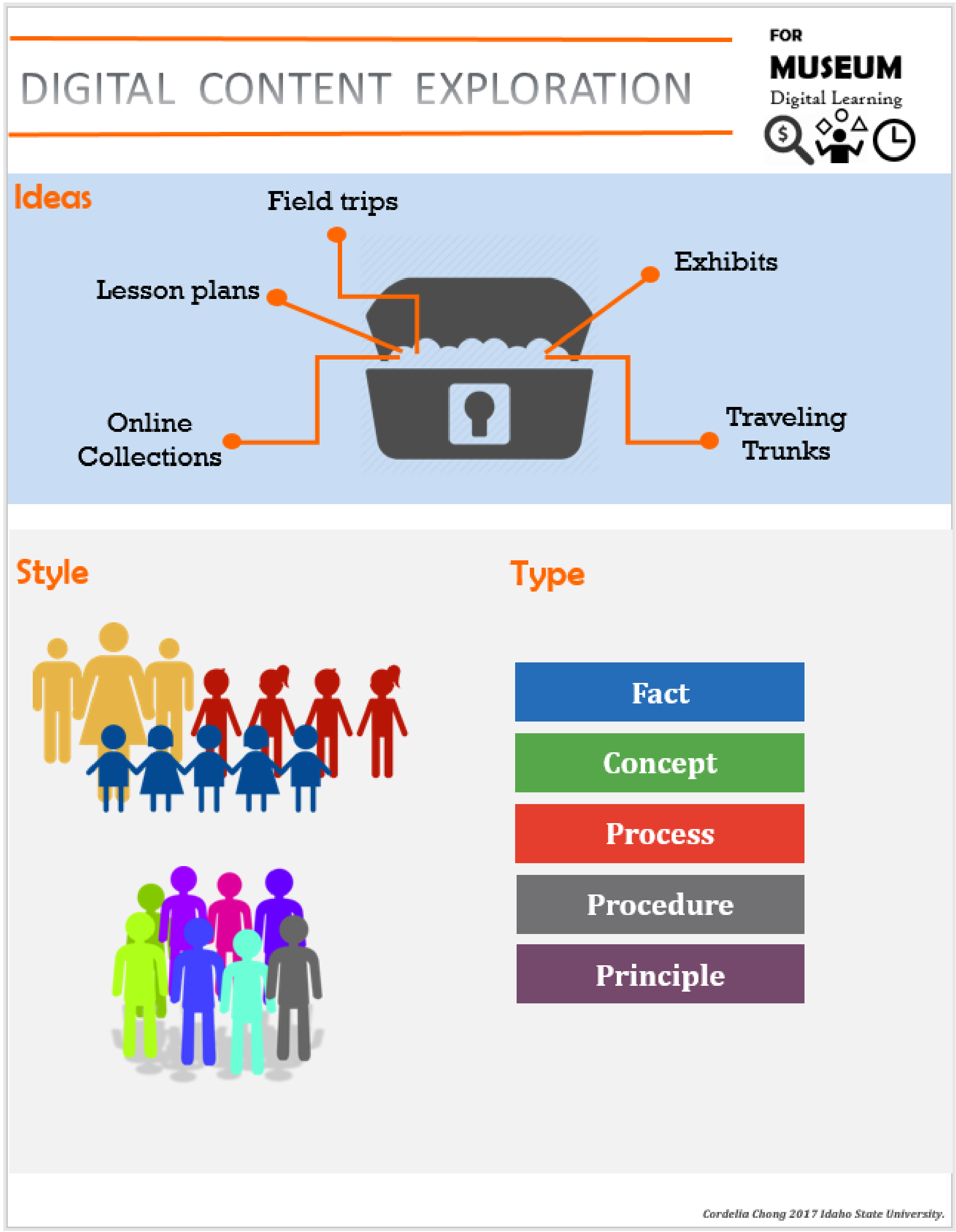

Figure 5.3 The three aspects to consider at the content exploration stage: content ideas, style of learning, and type of content.

Figure 5.4 The 2016 Evolving Idaho exhibit at the Idaho Museum of Natural History (IMNH).

The content ideas for this case study came from the Evolving Idaho exhibit at IMNH in 2016. This approach is in line with the recommendation for informal science learning (National Research Council, 2009): "When possible, such exhibits and environments should be rooted in scientific problems, ideas, and activities that are meaningful to these local communities." The Evolving Idaho exhibit was organized by Idaho State University Professor Rick Williams, who is also the research curator of the Ray J. Davis Herbarium (Figure 5.4).

The enthusiasm of local experts, who are serious about environmental stewardship, can inspire learners to become informed citizens on important local conservation issues. This is because when it comes to the observation of local flora and fauna, the passion of local naturalists and their eagerness to convey the aesthetic component of nature are important additions to their credibility as scholars (Schmidley, 2005).

Sadly, it is not uncommon for children and young adults to be familiar with exotic wildlife in distant places while lacking even the basic knowledge of local flora and fauna (Lorsbach and Jinks, 2013). For learners, this form of digital learning offers a good balance of both familiar (digital tools) and new (unfamiliar native plants and animals). Additionally, broad concepts often have a familiar feel when local plants and animals are depicted in the lessons.

While the same content can be designed for different age groups, the learning platform sometimes determines the target audience. For example, the American Museum of Natural History (n.d.) offers a long list of educational games on their "Ology" website for children. Even though a practical digital learning platform does not come with gamification software, links to educational games can always be included in the content. Given that most museums already offer fun on-site activities for children, the typical target audience for online museum learning is late teens and young adults who do not visit museums as frequently as younger students (Tota, 2012).

When it comes to matching content with a target audience, a survey by the Smithsonian Institution (2007) found that motivation in younger museum audience is only loosely connected to the subject matter but instead "closely linked to learning, connecting, and experiencing in a broad sense." To put it another way, it is the style of an activity that promotes learning outside the classroom, not necessarily the learner's knowledge or specific interest in a subject matter. With this awareness, museum educators can focus more on the style of a learning activity and less on topic selection. This insight also encourages a cross-disciplinary exchange of ideas because what works in a natural history museum may also work in an art museum.

Along these lines, the most accurate way to define a target audience for museum learning is not always age, as stated in a report by the Denver Art Museum (2012): "We originally thought of this audience as an age group but later realized that style, not age, was a better way to categorize the target audience." People who live a digital lifestyle use digital devices as an enhancement to all aspects of life, be it at home, at work, at school, or at play. Therefore, a person's learning preferences are likely shaped by their current use of digital devices, not by the technology available when they were growing up. That is why many adults have extensive digital literacies but some youth do not (Dede, 2014). For this reason, I decided not to specify a target audience even if the style of learning is generally preferred by late teens and young adults.

Within every content idea, the educator can choose the type of content to present and the performance level expected of the learner. The **Component Design Theory** (CDT) by Merrill (1987) is grounded in Gagné Conditions of Learning (1970) that each type of content can have different instructional goals. Table 5.2 shows a simplified version of the two dimensions recommended by CDT with five general types of content:

- Facts (pieces of information such as numbers and names)
- Concepts (objects or events with similar characteristics or properties)
- Process (a flow of events or activities)
- Procedures (a specific sequence of steps)
- Principles (governing rules or guidelines)

Table 5.2 A simplified matrix of the Component Design Theory (CDT) by Merrill (1987), with five types of content and two performance levels.

Performance Level	Types of Content				
	Fact	Concept	Process	Procedure	Principle
Remember	Recall the fact	Recall the definition of Concept A	Recall the steps of Process A	Recall the steps of Procedure A	Recall the guidelines
Apply	Not applicable	Compare and contrast Concepts A and B	Use the knowledge of Process A in a new situation	Demonstrate Procedure A	Apply the guidelines in a new situation

The performance levels indicate how learners will use the content – to recall the information (remember) or to apply knowledge to a specific case (apply). What is not obvious about the CDT matrix is that each matrix cell can be designed as a stand-alone learning unit, thereby allowing learners to decide the number of units they want to explore in one setting as well as the order in which they will proceed. This approach offers learners more control of their own learning. For instance, Learner A may choose to explore all content types at the "Remember" level before proceeding to the "Apply" level. Learner B, however, may cover both performance levels for one content type at one time.

The most notable limitation of the CDT is an emphasis on the components and not the integrated whole (Merrill et al., 1990). However, this may not be a major concern for museum educators because online museum learning resources are usually not aimed at the comprehensive coverage of a topic. So educators can select the type of content (facts, concepts, process, procedures, or principles) as well as the performance level (remember or apply) based on specific goals. In this study, I designed interactive learning units to complement a physical exhibit so the goal was simply to highlight some facts (Figure 5.5) and concepts (Figure 5.6).

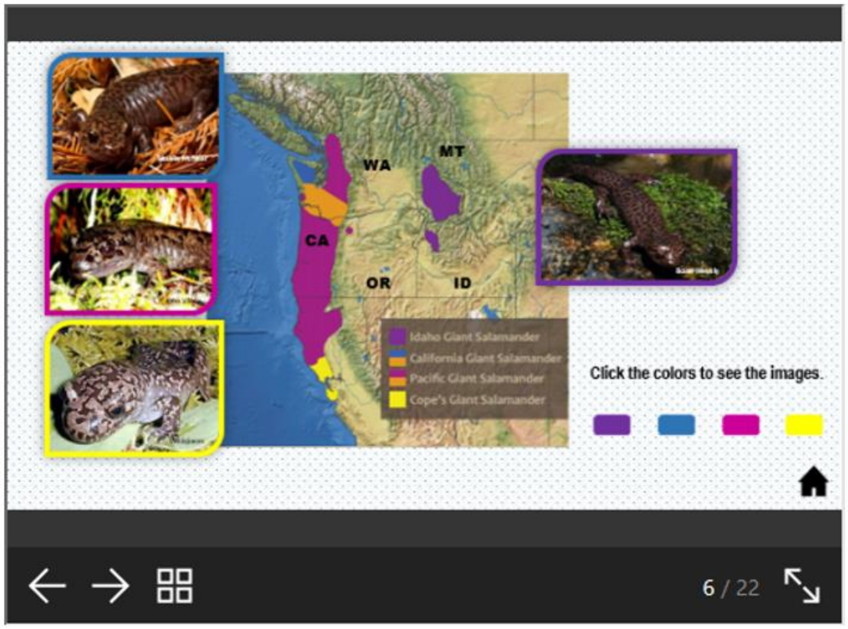

Figure 5.5 An example of facts presented in the learning unit on giant salamanders.

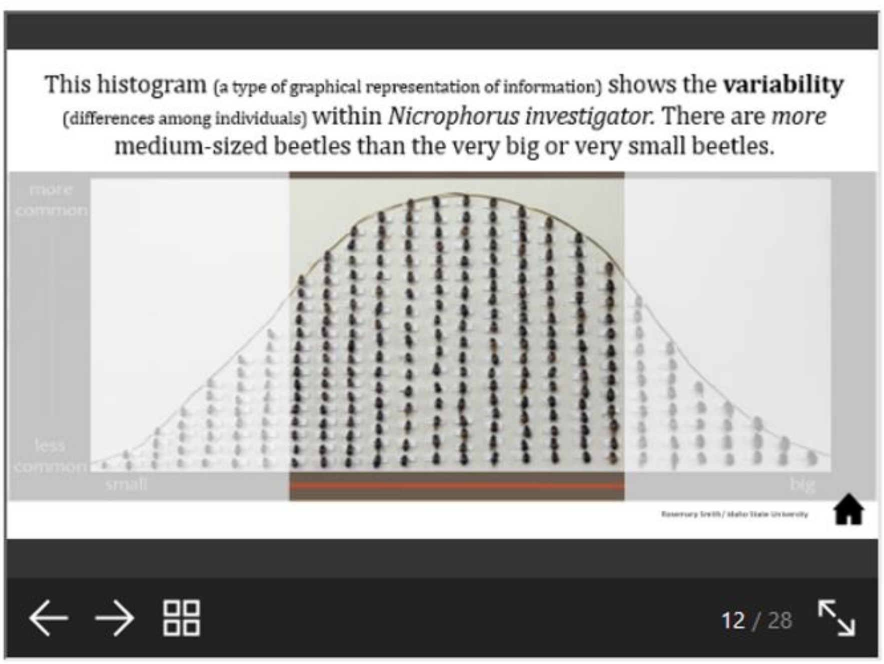

Figure 5.6 The concept of variability presented in the learning unit on burying beetles.

Step #2: Design-Develop (Motivation to Learn)

After completing the "Analyze" step, museum educators will need to make certain design choices even when using templates that come with out-of-the-box features. In this section, design elements that have been shown to promote our motivation to learn in a digital environment will be highlighted. When it comes to learning with words and pictures (multimedia learning), scholars have only in recent years investigated the affective perspective (motivation/emotion) by asking questions like, "How can we design multimedia learning materials with visually appealing elements that can promote learning?" (Plass et al., 2014). As such, this emerging field is not well defined and the terminology can be obtuse.

Instead of using the term "informal learning", Dierking and Falk (1998) refer to the life-long, self-motivated learning that can take place outside of the classroom as **free choice learning**, simply because the learner decides what, where, when and how he/she learns. Packer (2006) described free choice learning as an "experience that is valuable for its own sake, regardless of the presence or absence of learning outcome" (p.341). At the very least, museum learning is enjoyable simply because it is self-paced, non-consequential, and voluntary.

Lin and Gregor (2006) summarized that "Enjoyment can be derived from learning, as learning satisfies a number of human needs, but it needs to be learning that is accompanied by positive effect." Lin, Gregor & Ewing (2008) subsequently identified three basic dimensions to learning for enjoyment: engagement (e.g., engrossed, focused), positive affect (e.g., pleased, satisfied) and fulfillment (e.g., worthwhile, rewarding); all three dimensions are closely linked to human motivation.

The intrinsic motivation in museum learning has been studied to a certain extent. Csikszentmihalyi and Hermanson (1999) discussed the key notion of "interest" by extending on the work described by Dewey (1913), and Hidi, Renninger & Krapp (1992):

> Situational interest occurs when one encounters tasks or environments with a degree of uncertainty, challenge, or novelty. Once evoked, situational interest can result in curiosity and exploratory behavior; therefore, certain contextual stimuli can serve as the "hook" for museums to capture visitor attention.

More recently, Schwan, Grajal & Lewalter (2014) reviewed the similarities between learning for fun and the motivational aspect of learning in several research topics: intrinsic motivation (Ryan & Deci, 2000), situational interest (Hidi & Renninger, 2006; Krapp, 2002), and curiosity-driven museum visits (Rounds, 2004). The authors found a strong connection between positive emotions and intrinsic motivation. Isen and Reeve (2005) concluded that positive emotions foster intrinsic motivation in non-academic learning situations, defined as "the motivation to engage in a task for its own sake – out of interest and/or enjoyment – and not as a means to another reward."

Most of the time, intrinsic motivation is derived either from personal interest (e.g., I have always liked X so I want to learn more about X) or situational interest (e.g. X looks interesting so I am curious about X). That is, we may go to the museum to learn more about what we already like (personal or individual interest) or we may unexpectedly learn something new at the museum when we become curious (situational interest). Cultural institutions are known to generate situational interest by impressing visitors with visually appealing exhibits integrated with novelty. In this digital age, museums can attract more visitors through their websites that offer online learning, entertainment, as well as life and knowledge enrichment (Pallud & Straub, 2014).

In his book, *The Art of Changing the Brain*, Zull (2002) devoted an entire section on intrinsic motivation. It appears that student emotion has a strong influence on motivation. For example, positive emotions such as confidence have been associated with deep processing while negative emotions such as anxiety have been associated with more superficial processing. One way educators can promote positive emotions is to present a challenge, neither too difficult nor too easy, so the learner can experience a sense of accomplishment and become motivated. This strategy is a major tenant of the **Flow Theory**, first described by Csikszentmihalyi (1990). The theory may not sound familiar to most people but in everyday language, the flow experience is often referred to as being "in the zone" or "focused".

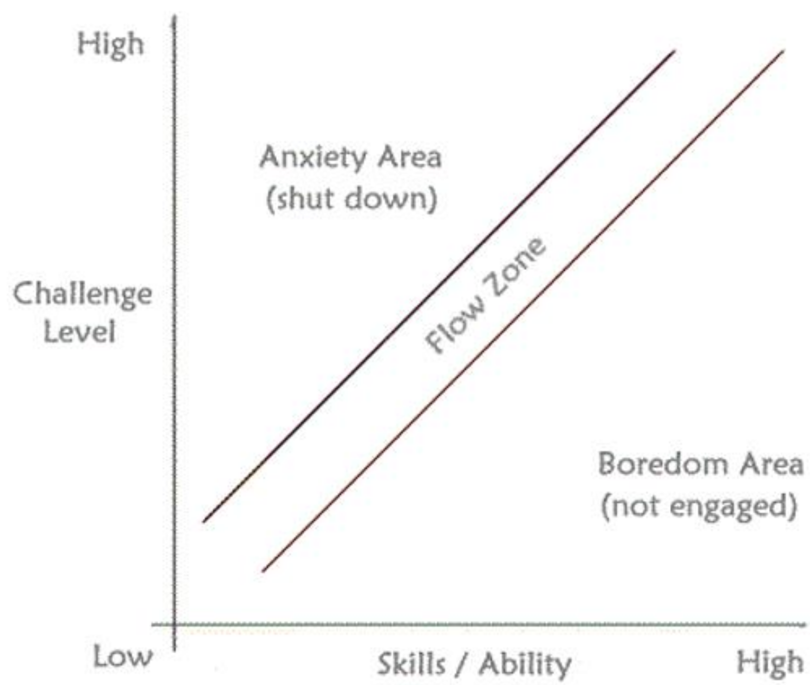

Figure 5.7 The Flow Theory by Csikszentmihalyi (1990).

As shown in Figure 5.7, Csikszentmihalyi (1990) insists there must be a balance between skill and challenge levels because negative emotions such as boredom, frustration, and anxiety are symptoms that a learner is not in flow: “Enjoyment appears at the boundary between boredom and anxiety, when the challenges are just balanced with the person’s capacity to act.” In contrast, a learner who has at least a 50-50 chance of being successful at his/her task will likely lose track of time and space, which exemplifies the flow experience. That is why educational games are designed to have multiple levels because learners who win one level are motivated to try the next level and so forth. In the process, learners are gradually challenged with greater levels of difficulty in a progression that allows them to be successful in incremental steps (Oblinger, 2004).

In relation to web design, Pace (2004) found that poorly designed websites reduced the likelihood of “flow” experiences. By designing flow-enhanced online college courses, Rodríguez-Ardura & Meseguer-Artola (2016a) documented at least three benefits for learners: positive emotions, better academic performance, and continuance intention as measured in the following semester. The authors (2016b) also found that adding interactivity to flow-enhanced contents can promote the imagination of learners, which allowed learners to experience better content engagement: “Interactivity influences the learners’ responses through the intervening effects of imagery, spatial and copresence, and flow.”

When it comes to multimedia learning, the role of motivation has been largely underspecified until recent years. The **Cognitive-Affective Theory of Learning with Media** or CATLM proposed by Moreno (2006) has only been recently refined and extended by Um et al., (2012) and Plass et al., (2014) who introduced the **Emotional Design Hypothesis**. To put it simply, an emotional design is the use of visual design elements such as graphics, color, and shapes. Some scholars postulated that certain design choices (e.g., anthropomorphism, warm colors) can evoke positive emotions by making the essential elements in the lesson more appealing, without distracting the learner from the learning goal (Mayer & Estrella, 2014).

It is assumed that how users perceive the visual appeal of a website can trigger an emotional response (e.g., satisfaction, pleasure) that influences subsequent responses (e.g., approach or avoidance). When it comes to Web aesthetics, a good first impression goes a long way. In fact, people tend to be more satisfied with a visually appealing Webpage that performs at a suboptimal level than with a user-friendly Webpage that lacks visual aesthetics (Lindgaard et al., 2006). The challenge for museum educators is to choose design choices that can evoke positive emotions, which may then promote subsequent visits to the museum, both onsite and online.

Decorative Pictures. In this visual information age, there is, even more, value in the cliché, "a picture is worth a thousand words." While physical museums are known as a place of learning, they are also known as beautiful places; naturally, visitors will also expect museum Web offerings to be visually pleasing (Pallud and Straub, 2014). One way to increase the visual appeal of a website is to use visually stunning images.

Within the context of multimedia learning, adding pictures to an instructional text is supported by abundant research (Clark & Mayer, 2016). In fact, graphics can support learning in so many diverse ways that Danielson, Schwartz & Lippmann (2015) suggested that current taxonomies (e.g., Carney & Levin, 2002) are no longer sufficient to "account for the functional range of graphical representations." For the purposes of this dissertation, instructional pictures (IP) refer to graphics designed to support the learning goal (e.g., illustrated diagrams and concept maps) and decorative pictures (DP) refer to stock images, which are photographs of common places, landmarks, nature, events or people (Lenzner, Schnotzn & Müller, 2013).

In spite of their instructional value, IP are often beyond the reach of most museum educators because IP are generally custom designed by a team of professionals. In contrast, decorative pictures (DP) available on photo-sharing sites like Flickr are accessible to everyone and should not be overlooked for their potential roles in learning. Furthermore, textbook publishers consistently include DP with expository texts along with IP, indicating that DP plays some role in promoting learning. Therefore, the first guiding question of this section is: "Can decorative pictures (DP) be used as visual design elements for online museum learning?"

One recurring theme in any museum learning research is the lack of studies that take into account the specific conditions of informal learning. This is no exception – the empirical evidence for using DP comes from classroom research, with most findings pointing to the connection between DP and positive emotions.

Schneider, Nebel & Rey, 2016) recommended using DP of people with positive emotions, instead of neutral or negative, and in a learning environment (e.g., students doing a science experiment) and not a leisure setting (e.g., students chatting in the dining hall). The preference for human faces was confirmed in an earlier study using eye-tracking, which showed that participants "gave higher visual appeal ratings to homepages that include images of people" (Djamasbi, 2014).

Magner et al., (2014) reported that middle-school students with low prior knowledge can be negatively affected by DP, and ended up not doing well on even the less demanding recall tasks. This is mainly due to the distracting nature of DP, known as the "seductive detail effect" (Mayer and Estrella, 2014); implying a tension between learning motives and entertainment motives of learners (Schwan et al., 2014).

However, the “seductive detail effect” was not observed in the study by Lenzner et al. (2013) because middle-school students with low prior knowledge actually benefited from the synergistic effects of IP and DP. Interestingly, the DP only group experienced higher learning enjoyment through “better mood, higher alertness, and calmness”. The positive emotions induced by DP possibly also improved the confidence of the DP group because they were the only participants who rated the learning material as less difficult. This finding is similar to that reported by Um et al. (2012) that learners who experienced position emotions also perceived the learning materials as less difficult, became more attentive. They also reported higher levels of motivation and satisfaction.

These results led several authors to conclude that DP alone are neither harmful nor beneficial when it comes to improving learning outcomes, and the use of both IP and DP is ideal. In spite of having only had a minor impact on learning outcomes, DP and other emotional design elements can have a larger impact on learners’ intrinsic motivation, including the motivation to continue working with the material (Heidig, Müller & Reichelt, 2015).

The emerging evidence on the positive effect of DP on learning comes from Danielson et al. (2015) who utilized DP as visual analogies. The authors reported better retention after one week delay by participants who learned about a civil war with expository text and DP that depicted two lions of similar size and color engaging in aggressive combat. The authors speculated the additional processing of DP may serve to reinforce and preserve learning over time.

Even though the impact of DP on classroom learning is not clear-cut, the potential role of DP in evoking positive emotions such as learning enjoyment and learner confidence makes DP a valuable asset for informal learning, where learning is not driven by grades but by a combination of discovery and enjoyment (Packer, 2006). Fortunately, nearly any kind of interesting graphics may be appropriate for leisure learning because attention-grabbing visuals generally cause a more intense emotional reaction than text (Sung and Mayer, 2012).

In addition to using high-quality stock images, museum educators can also seek out local photographers and artists – either by getting permission to showcase their work or by collaborating with them to create customized visuals. In this case study, I worked with the following talented local photographers: Dr. Chuck Peterson, Ms. Becky O'Neill, and Mr. Dave Bush. Instead of going through the tedious process of seeking permission from photographers who are not familiar with this project, I was able to work with individuals who are not only excited about the project but were eager to contribute.

The second guiding question of this section is related to the placement of DP: "What is the best way to integrate DP into online learning content?" The answer may lie in visual appeal research, which is becoming increasingly relevant mainly because of Generation Y, who is now the largest generational segment of the U.S. population and spends almost $200 billion a year (Solomon, 2015). These individuals are born after 1980 and so, technology was integrated into their lives at a very young age. As a result, they prefer to get information on the Internet and place more emphasis on web design aesthetics than Generation X and the Baby Boomers. For example, Generation Y individuals tend to associate merchandise quality with the visual appeal of the homepage of a retail site (Oh et al., 2008).

By transference, we can expect Generation Y to view other websites through the same critical lens, at least when it comes to web aesthetics. This was confirmed by Djamasbi, Siegel, & Tullis (2010) who used eye-tracking to confirm the characteristics identified by the Nielsen Norman Group as particularly appealing to Generation Y: a main large picture, little text, pictures of celebrities, and a search function. In this case study, I implemented two of the above design choices: a main large decorative picture and a small block of text (Figure 5.8).

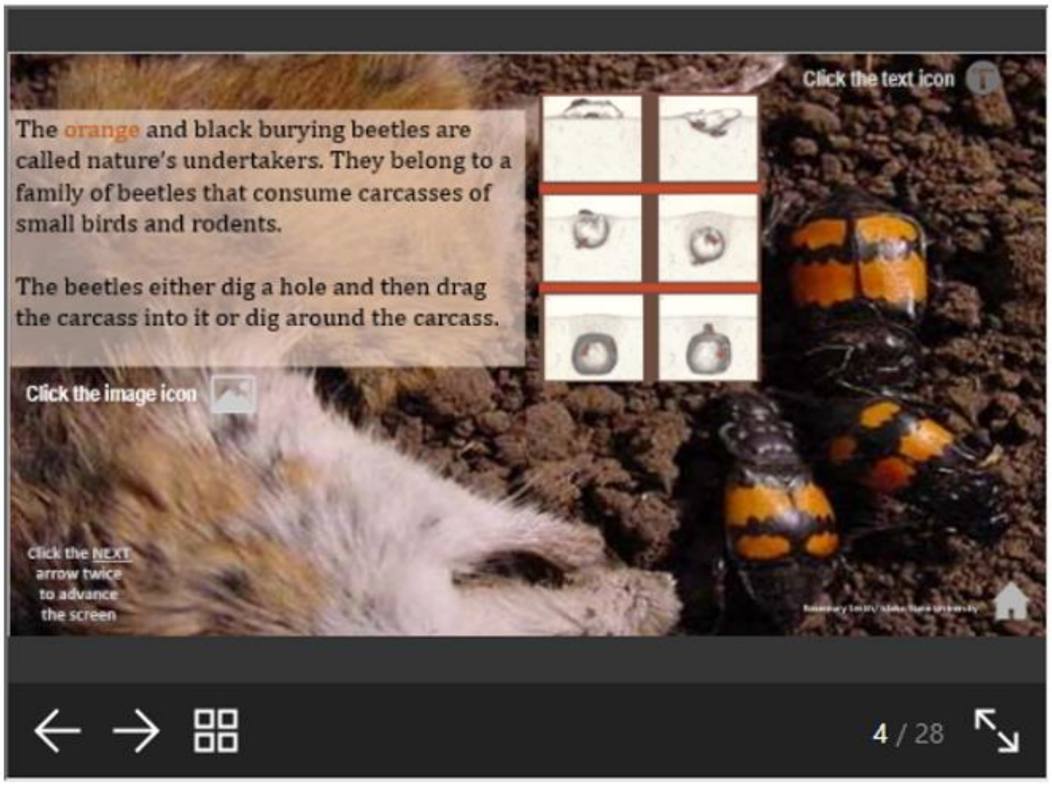

Figure 5.8 The use of a simple visual appeal strategy: a large main image and a small block of text.

Color and Typology. Since emotions can potentially change the way learners perceive the learning experience and thus change their ensuing learning behaviors, I wanted to explore other design choices that can enhance the positive emotions evoked by visually stunning DP. Even though a holistic approach is often suggested, a discussion of the more concrete design elements associated with positive emotions can be a helpful guide for many educators. Therefore, the third guiding question of this section is, “What are some of the concrete visual design features that can improve the overall web appeal?”

According to Lavie and Tractinsky (2004), there are two basic dimensions to the perception of website aesthetics. While clear, pleasant, and symmetrical design choices are the hallmarks of the traditional notions of aesthetics, designs based on expressive aesthetics are creative, fascinating, and even unconventional. Even though both approaches are well liked by users, websites with classic design elements are more strongly associated with factors like usability and service quality (Sonderegger et al., 2014). A quick survey of museum websites will reveal that most museums, except for some children or art museums, adopted the classic notions of web aesthetics.

Whether used with a classic or expressive design, color can have an enormous sway over our attitudes and emotions. Lindgaard et al. (2006) found that it takes just 90 seconds for a site visitor to form an opinion, positive or negative, and up to 90% of that initial interaction is determined by the color of a product alone. There are at least three reasons why color should not be overlooked: (1) color is universally known to have a marked impact on emotion and behavior, (2) right colors improve web aesthetics without adding distracting design elements, and (3) every color can be characterized in different ways (e.g., hue, saturation) to meet different design needs.

The science of how color affects human behavior is known as color psychology. In a nutshell, when we view a color, the wavelength is first converted into electrical impulses by the retina before reaching the hypothalamus or the master gland that controls the endocrine system. In turn, the hypothalamus signals the release of hormones which cause fluctuations in our mood, emotion and eventually, our behavior (reviewed by Kurt & Osueke, 2014). Even if the psychology of color is complex, museum educators can follow a few common guidelines, as reviewed by Heidig et al. (2015), to create a strong first impression on users:

- Choose complementary colors (opposing color pairs on the color wheel such as red/cyan, blue/yellow or green/magenta),
- Maximize contrasts (one very light/slightly saturated and the other one very dark/fully saturated)
- Choose similar colors (variations of one color by adjusting the saturation, brightness, etc.)

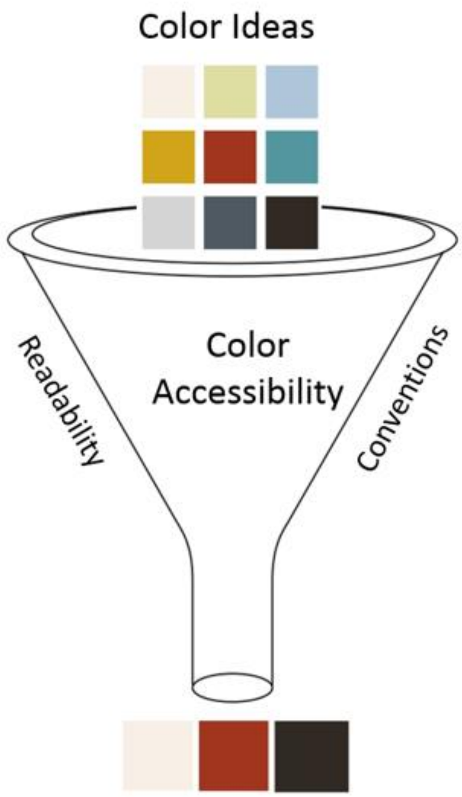

Figure 5.9 A two-step approach in choosing colors for digital content: start with a few color ideas, and narrow the choices down based on color accessibility.

In this case study, I consolidated commonly used guidelines and simplified the approach into two steps: **color ideas** and **color accessibility** (Figure 5.9). The goal is to start with a few color ideas and then narrow down to a few based on how the specific context. More often than not, designers do not start with random colors, but instead, borrow ideas from other design elements that must be included and are less negotiable than color. For example, the leadership of an organization may insist on a specific color identity. If those colors are somewhat inappropriate for learning materials, one way to resolve the dilemma is to use a muted palette that can go well with nearly every type of content (Malamed, n.d.).

The two main components of color accessibility are readability and conventions. It can be very frustrating for learners when the on-screen text is not easily legible, so readability always takes precedence over the visual appeal. The best practice is to use dark text on a light background, especially when there is a lot of on-screen text, and to use white text on dark background only sparingly (Pappas, 2014). In this context, the term “conventions” refer to the common wisdom associated with using certain colors. Here are a few examples (Legault, n.d.): (1) too much yellow can cause eye fatigue, (2) combinations of colors with red, green, or blue cannot be distinguished by individuals with color blindness or color vision deficiency (CVD), and (3) red is considered off-putting in one culture but auspicious in another.

Initially, I color-coded the modules to connect a topic to a specific color, only to find out that color-coding was not perceived as very appealing by most study participants. Eventually, I decided on a minimalistic design by using just the key colors from the photographs featured in the content and applied muted variations to create both contrast and harmony (Figure 5.10).

Figure 5.10 In this example, muted variations of the key colors in the photograph are used to create both contrast and harmony.

The arrangement of text on a screen, also known as **typography**, can also affect web aesthetics. A "wall of words" is never advisable for even formal online learning, which is why informal learning resources are usually not text-heavy. The right balance of text, graphics, and white space helps learners read, organize, and focus in on the most important information. As shown in Figure 5.9, I kept the text to a minimum for "impatient users", as suggested by Loranger & Neilsen (2013):

> Nothing deters younger audiences more than a cluttered screen full of text. Teens can quickly become bored, distracted, and frustrated. Display content in *small, meaningful chunks* with

plenty of *white space*. Small chunks help teens retain information and pick up where they left off after the inevitable interruptions of text messages and phone calls.

I found that an easy way to create "small and meaningful chunks" is by using text boxes and following a few general rules (Pappas, 2015b):

- **Font size**. At least 18-20 for paragraphs, larger for titles and subheadings.
- **Line length.** A line of text should not have more than 75 characters.
- **Letter and word spacing.** This is different from the white space between text and image. Apart from the space between lines, the distance between letters and words can also influence readability as well as draw attention to certain words.

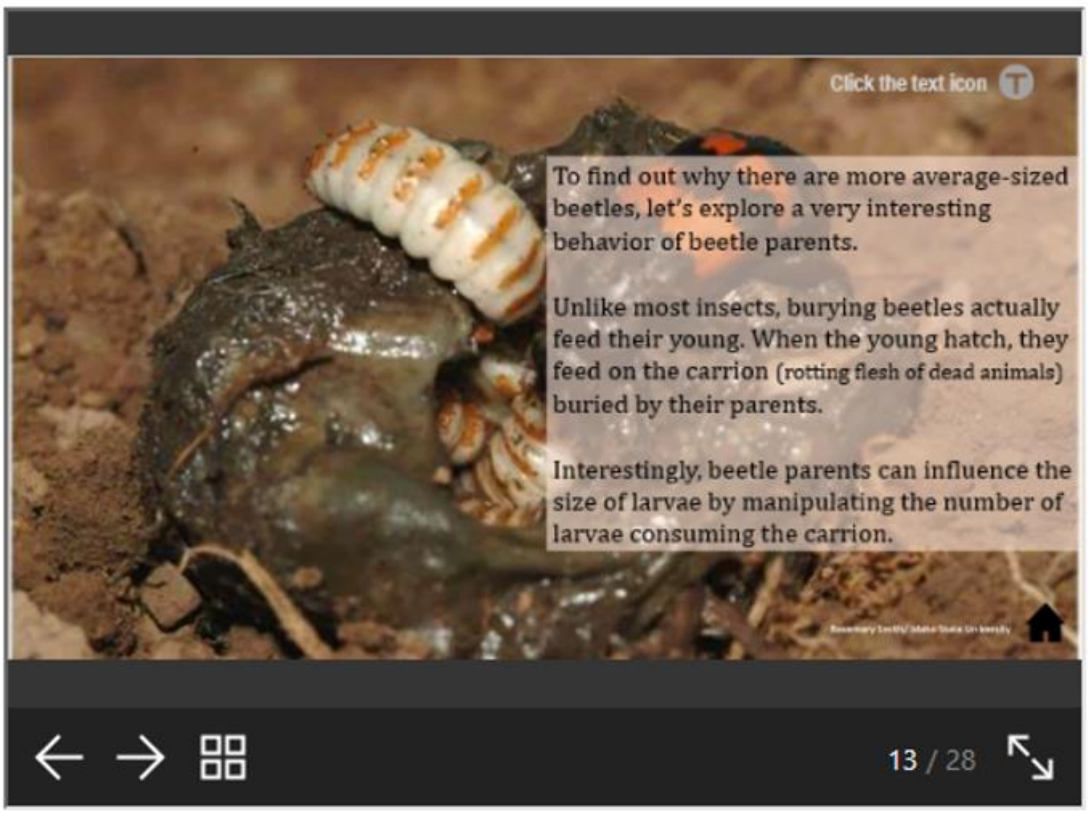

Figure 5.11 In this example, small and meaningful chunks of information is presented by using a text box and by following a few general rules.

Formative Assessment. Another effective way to promote positive emotions is to allow learners to experience a sense of achievement. This can be done by interspersing assessment items so learners can use the new knowledge to achieve some goal (Figure 5.12). Zull (2002) elaborates by discussing pleasure and movement: "Success is progress toward a goal, and nothing succeeds like success. This could be one of the most important aspects of intrinsic motivation. Achievement itself is rewarding, and that may simply be because it is recognized as movement" (p.62).

But there is more – there must be a balance between skills and challenges for learners to experience any personal satisfaction, as suggested by Csikszentmihalyi (1990). This is particularly pertinent to informal learning, which is driven mainly by intrinsic motivation. An achievement that is attributed to intrinsic motivation enhances the self-esteem of an individual, which in turn can lead to a greater sense of security and confidence (Zull, 2002). Importantly, formative assessment can be designed to meet the three main conditions proposed in the Flow Theory:

- **Goals** – Even in free choice learning, the learner has to make a deliberate effort to explore. These decisions can be encouraged by clear learning goals as well as self-paced learning content so learners decide when, where, and what to explore.
- **Balance** – A good balance between skills and challenges is necessary to enhance the intrinsic motivation that first initiated the free choice learning by giving learners a sense of achievement.
- **Feedback** – Immediate feedback allows the learner to make changes and improve his/her performance so the learner experiences the awareness that he/she is making progress with the task.

Office Mix® offers several assessment add-ons such as a multiple-choice template that comes with immediate feedback and hints. Similar to many online quiz makers, the educator has the following options for each multiple-choice question:

- single or multiple attempts
- single or multiple correct answers
- whether to scramble answers
- whether to provide hints
- whether to provide elaborate feedback (EF)

The default setting for feedback is knowledge of results or KR, which is given immediately after a response is submitted to indicate if the response is correct or incorrect. However, the option for elaborated feedback or EF is available so an explanation for both correct and incorrect answers can be provided.

To achieve a good balance between skills and challenges, I designed the assessment tasks for novice learners by dispersing multiple-choice items throughout the learning content (Figure 5.12). Each item comes with immediate feedback, either KR or EF, based on the nature of the question. Since the learner has control over the flow of information, he/she can revisit previous screens to go over the content again. For that reason, answers to multiple-choice items are always scrambled to make any repeated attempts more challenging.

After a mix has been published and viewed by at least 10 different users based on IP addresses, Office Mix® begins to collect data for all the assessment items by providing basic indicators such as the number of views, number of attempts, average number of hints used, and time spent on each item. The answers are color-coded and conveniently, the analytics can be exported to Excel for more in-depth data analysis. As discussed in Chapter 4, learning analytics can provide valuable feedback on the design choices. Museum educators can use the score distribution to look for possible systematic misunderstanding that could be caused by the learning content or ambiguous questions, and decide what revisions are necessary.

Figure 5.12 An example of how assessment tasks are interspersed throughout a learning unit.

Even in technology-based classroom learning, there has been a move towards multiple-choice questions. However, technology does not make it easier to design good multiple-choice questions, mainly due to common problems such as ambiguous questions and obvious incorrect responses. It is equally challenging to create meaningful elaborate feedback. That is why many commercial platforms are experimenting with adaptive learning technologies, which have the ability to modify the presentation of material in response to a student's performance (Farrell & Rushby, 2016). There is more work involved in designing adaptive learning content because significantly more content has to be developed to cover every track, even if only a small portion of it will be used by an individual student.

The A.S.S.I.S.T Framework. As apparent, there is no unifying framework for educators to apply design choices that can promote positive emotions. To counter this dilemma, I consolidated several research findings under the acronym A.S.S.I.S.T: Appeal, Style, Structure, Interest, Support, and Tasks (Table 5.3). The design conditions are derived mainly from a handful of studies that examined the unique conditions of informal learning. Lin and Gregor (2006) first examined "design features and informal learning from the viewpoint of web designers and educational experts." This was followed up by an exploratory study that analyzed the learning and enjoyment experiences of a large number of online museum visitors (Lin et al., 2012). I grouped the design conditions under the three dimensions described by Lin et al. (2008): positive affect, engagement, and fulfillment.

The A.S.S.I.S.T framework also takes into account the suggestions offered by educators who emphasized the holistic approach of integrating aesthetics into the learning experience. Porter (2017) echoes the view of Parrish (2007), who argues for a view of learning as an experience beyond the surface quality of things: "Aesthetics relate to the learning experience through instructional design principles, but it is also more holistic in its nature."

With the growing interest in emotional design and positive emotions in multimedia learning, the A.S.S.I.S.T framework captures only a "part of the whole", and is by no means comprehensive. The framework represents my attempt to gather a more coherent view of ideas from different academic disciplines. Otherwise, educators must select from amongst the many research findings, and then adapt and apply them as appropriate.

Table 5.3 The new A.S.S.I.S.T framework stands for appearance, style, structure, interest, support, and tasks.

Dimension of Enjoyment (Lin et al., 2008)		Design conditions	Main references
Positive affect (pleased, satisfied)	Appearance	Design: Classic or expressive Picture: large image, faces of people, anthropomorphisms Color & typology	Djamasbi et al.(2010) Emotional Design Hypothesis Heidig et al. (2015) Lavie and Tractinsky (2004) Porter (2017)
Engagement (engrossed, focused)	Style	User control Interactivity Multisensory	Lin et al. (2012) The Flow Theory
	Structure	Clear learning goals Storylines/plots (Gagne's Nine Events of Instruction, The 5-E Model, The Inquiry Cycle)	Lin et al. (2012) Parrish (2009) The Flow Theory Zull (2002)
	Interest	Novel ideas New topics	Lin et al. (2012) Packer (2006)
Fulfillment (rewarding, worthwhile)	Support	Social media External resources Cross-platform compatibility	Lin et al. (2012)
	Tasks	Simple and easy Good balance of skills and challenges Feedback learning	Lin & Gregor (2006) Packer (2006) The flow theory

When designing complex science content, museum educators can provide more structure to learning experience by applying instructional methods widely used in classroom learning, such as Gagne's Nine Events of Instruction, the Inquiry Cycle proposed by Llewellyn (2012), and the 5-E Model (Bybee et al., 2006). In Table 5.4, I consolidated these learning models with a few key tasks listed on the National Institutes of Health (n.d.) website, *Doing Science: The Process of Scientific Inquiry*.

Table 5.4 Guides for providing structure to the learning experience: Gagne's Nine Events of Instruction, the Inquiry Cycle (Llewellyn, 2012) and the 5-E Model (Bybee et al., 2006).

Gagne's Nine Events of Instruction	Inquiry Cycle	5-E Model	What the teacher does	What the students do
Gain attention	Inquisition	**Engagement**	Piques students' curiosity and generates interest	Express current understanding of a concept or idea
Describe the objective Stimulate recall of prior knowledge	Acquisition	**Exploration**	Asks probing questions to help students make sense of their experiences	Try different ways to solve a problem or answer a question
Present the material Provide learner guide Elicit performance	Supposition Implementation Summation	**Explanation**	Asks questions that help students express understanding and explanations	Explain concepts and ideas in their own words
		Elaboration	Encourages students to use what they have learned to explain a new event or idea	Draw reasonable conclusions from evidence and data
Provide feedback Assess performance Enhance retention and transfer	Exhibition	**Evaluation**	Observes and records as students demonstrate their understanding of the concepts and performance of skills	Assess their own progress by comparing their current understanding with their prior knowledge

Step #4: Design-Develop (Capacity to Learn)

Within the context of multimedia learning, scholars have considered mainly the cognitive (head/thinking) perspective by asking questions like, "How can we design multimedia learning materials that are effective for learning based on cognitive models?" (Plass et al., 2012). The National Research Council (2013) offers a concise overview of this growing research area:

> Research on learning with multimedia tools has led to the development of the cognitive theory of multimedia learning, derived from the **Cognitive Load Theory (CLT)**. This theory posits that learners experience cognitive demands during learning, but their limited processing capacity restricts the amount of cognitive processing they can engage in at any one time.

Cognitive Theories and the Modified Brain-Computer Analogy. The **Cognitive Load Theory (CLT)** was first described by Sweller (1988) and builds upon a pre-existing model of human memory by Atkinson & Shiffrin (1968). Subsequently, Mayer (2009) derived the **Cognitive Theory of Multimedia Learning (CTML)** from several cognitive theories, including the CLT. All the cognitive theories focus on the "cognitive processing during learning within a working memory of limited capacity using knowledge activated from a long-term memory with unlimited capacity." The multimedia design principles stemmed from the CTML (Clark and Mayer, 2016) and are widely used by designers to ensure they stay away from design choices that might interfere with the learning experience. In short, these design principles can enhance our capacity to learn with words and pictures.

Apart from working memory (WM) and long-term memory (LTM), the cognitive architecture also includes the sensory memory. I modified the conventional brain-computer analogy to visualize these memory systems: LTM as a cloud-based server that has unlimited storage and WM as a tablet that can only process a limited number of applications at one time. But first, an overview of the systems is necessary for a deeper appreciation of the cognitive theories.

The sensory memory serves as the entry point for all incoming information and operates on two channels – one for processing auditory cues and another for visual information. Even though the sensory system can technically receive an unlimited amount of information (e.g., you can listen to music all day long), each channel has a predetermined limited capacity at any given time. That is why listening to music (audio) while browsing the Internet (visual) requires less overlapping effort than talking on the phone (audio) while listening to a podcast (audio). From an instructional standpoint, both the auditory and visual channels should be utilized but not overloaded (Paivio, 1990).

Much of the information perceived by the sensory memory does not reach the working memory (WM). Each channel can only hold any given piece of information for a few seconds with almost all information lost after 30 seconds, unless the person pays close attention (Mayer, 2009): “The learner can attend to some of the fleeting information in the sensory memory, which is called the cognitive process of selecting, thereby bringing it into working memory.” That is why we remember a new name or phone number by repeating it and writing it down. If that happens, the information is then brought to WM.

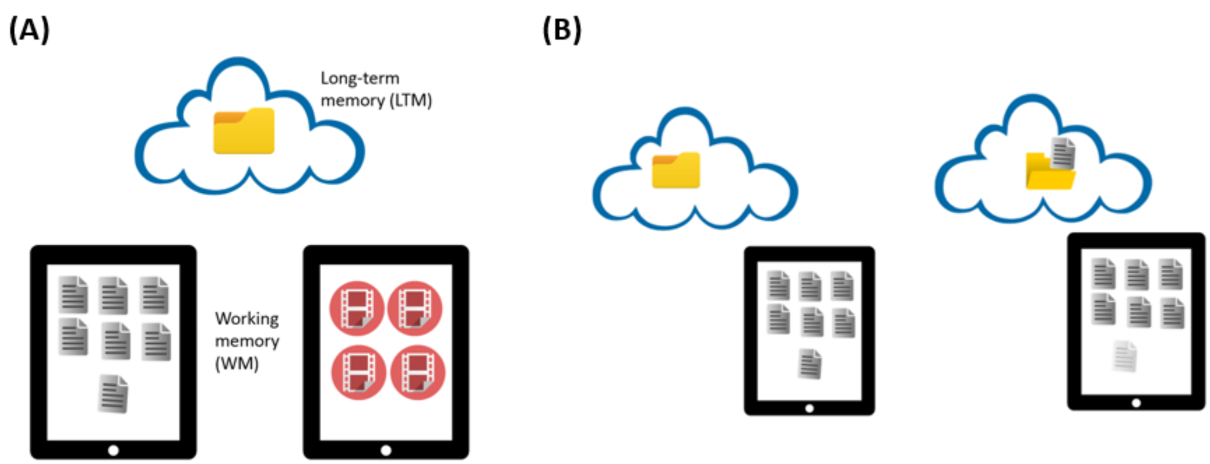

Figure 5.13 Using a modified brain-computer analogy to visualize the memory systems. (A) Long-term memory (LTM) as a cloud-based server with unlimited storage, and working memory (WM) as a tablet that can only process a limited number of applications at one time. (B) Once a “file” is saved in a “folder” in LTM, it is no longer “open” in WM, thus freeing the space for another file to be processed in WM.

From our own experiences, we know WM has a very limited capacity. According to Miller (1956), WM can only hold up to 7 (± 2) pieces of information at any given time; but Hardman and Cowan (2015) proposed that the capacity is highly task-specific, and can be as low as 4 or 5 elements. Using the modified brain-computer analogy, the widely accepted view of Miller and Cowan is analogous to how the screen of a tablet would freeze if more than seven Word documents are running simultaneously, but it takes only four video files playing at the same time to freeze the screen (Figure 5.13a).

In recent years, several studies have proposed an updated view of WM. According to Ma, Husain & Bays (2014), "WM might better be conceptualized as a limited resource that is distributed flexibly among all items to be maintained in memory. According to this view, the quality rather than the quantity of WM representations determines performance." Unsworth & Robison (2015) provided evidence that "individuals differ in both the number of items that can be maintained and the ability to control attention to prevent fluctuations in attention."

What remains unchallenged up to this point is the very low retention time in WM – mere seconds before it is forgotten, unless it is refreshed or integrated into LTM. Zull (2002) offers a unique perspective on the limited capacity of WM:

> If working memory could hold more information or hold it longer, we might not be able to reason as well as we do. We might waste time on irrelevant things, not notice the important things, develop overly complex plans, and ultimately find that our thinking was greatly slowed, maybe so much that we couldn't survive.

Unlike WM, LTM is theoretically limitless in its capacity for information storage. In LTM, information is organized in domain-specific cognitive structures known as schemata. The concept of schemata is similar to the folders we use to organize files on a computer. Just as how related files are saved in a folder, a schema contains multiple related pieces of information. For example, a folder labeled driving would contain all the files saved by a person, which effectively represents the person's prior knowledge in driving. In contrast, a person just learning how to drive would likely have separate files on parking, changing lanes, and so forth.

Zull (2002) calls the conscious rearranging and manipulation of items as thinking: "Although they are separate, WM is not unrelated to LTM. When we use things in WM to do some work, to create something new, then that new thing can become part of our LTM" (p.182). The same process is described by Mayer (2009) as the cognitive process of organizing: "Within WM, the learner can organize incoming visual information into a spatial representation and the incoming verbal information into a verbal model."

It is always easier to retrieve a folder than to locate separate files on a computer. In the same way, information is organized as schemata in LTM for easy retrieval. Once located, a folder is opened so a new file can be quickly added to an existing folder. Once the file is saved in a folder located in the cloud-based storage (LTM), it is no longer "open" in WM, thus freeing the space for another file to be processed in WM (Figure 5.13b). These critical events are described by Mayer (2009) as the cognitive process of integrating: "Finally, the learner can integrate the spatial and verbal representations with each other and with relevant knowledge activated from LTM."

Expertise is largely dependent on LTM. An expert usually has well-organized folders in his/her area of expertise – those folders have very few irrelevant, redundant or duplicate files. The ability to retrieve folders quickly allows an expert to quickly compare any novel information against his/her extensive domain knowledge. Likewise, familiar tasks can be performed accurately when a schemata becomes fully automated, to the point when retrieval takes places without conscious effort (Sweller et al., 1998).

In contrast, a novice may not have any relevant folder in LTM to retrieve. As a result, the new files remain in WM, limiting the processing capacity of WM. During this time, any new information received by the sensory memory will be lost because the WM processing capacity is full. In that case, the new information must be redirected to the WM at a later time for processing. A crucial juncture in the learning process, therefore, involves the organization and integration of new information in LTM.

The Zull-Kolb-CLT Model/The new 4R Model. Cognitive theories are derived from decades of research on learning and the brain, especially on how information is encoded as memory. In the last two decades, there is a growing interest in using brain-based research to improve teaching and learning. In particular, Zull (2002) superimposed Kolb's popular four-phase model of the learning cycle on a map of the brain. By doing so, the flow of information becomes very apparent, and so does the need for learners to use all four areas of the cortex.

The four-phase model (i.e., feel, watch, think, and do) by Zull (2002) is very similar to the three cognitive processes (i.e., select, organize, and integrate) described by Mayer (2009). In effect, you *select* what you *feel*, you *watch* and *think* as you *organize* the information, then you *do* what is necessary to *integrate* the information. It appears the known stages of learning are more or less covered in all the phases of different learning models (Table 5.3), albeit at different levels. In the 5-E learning model, students *think* and *do* more in the exploration phase, but they still *feel* and *watch* as they interact with other students.

And there is more – Zull (2002) gave his book the title "The Art of Changing the Brain" because learning involves physical changes in the brain:

> The cells are called neurons, and the connections create neuronal networks…Not only is knowledge stored in the brain, it is produced by the brain through formation and change in neuronal networks. Any change in knowledge must come from some change in the neuronal network (p. 92).

Physicists Goldt & Seifert (2017) reinforced that view with the second law of thermodynamic: "Learning is just a transformation of a neural network at the expense of energy." Much like the bonding of atoms, the human brain finds the most efficient way to organize information – in the form of billions of neurons or massive neural networks. When extra energy is not put into a specific system, the strength of the system will get progressively weaker, known as entropy or a measure of disorder in a system. To put it another way, information that is received but not processed will eventually fade away because energy is not added to the system. Zull (2002) speaks of learning as changing the connections of neuronal networks:

> This is the change that a teacher wants to create. It is change in connections. We may want stronger connections, more connections, different connections, or even fewer connections, but unless there is some change in connections, no learning can occur (p.112).

Just as how Zull (2002) drew a compelling picture by overlaying Kolb's learning cycle onto specific areas of the brain cortex, I decided to integrate CLT into the Zull-Kolb model by using the modified brain-computer analogy. Based on my interpretation, CLT correlates very well with the Zull-Kolb model. To better reflect overlapping ideas, I named the four phases as "Reception", "Reflection", "Review" and "Retrieval" or the 4R model (Figure 5.14).

The 4R model also incorporated new findings on the hippocampus, located in the temporal lobe ("green" area in the 4R model) and described by Zull (2002) as the master integrator:

> In fact, it [hippocampus] is now thought to be on the route taken by all the information in the surrounding integrative cortex of the back cortex. The current idea is that sensory input, which has been integrated into images, patterns, faces, sounds, and location, all finds its way there (p. 81).

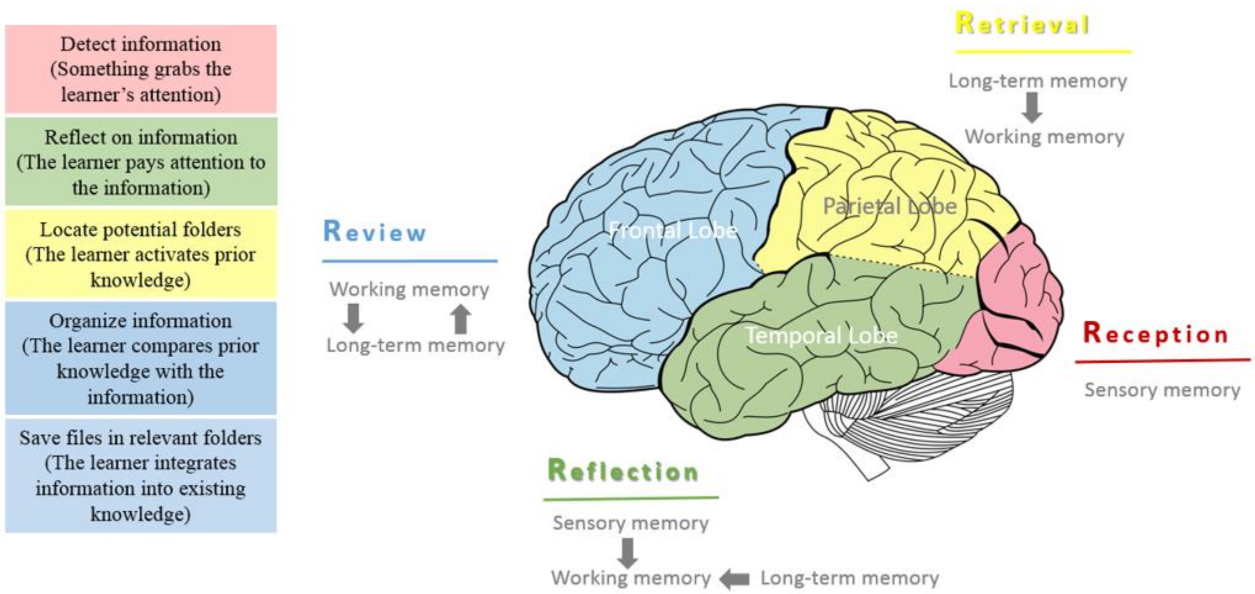

Figure 5.14 The initial 4-R model with four major cognitive phases (Reception, Reflection, Review and Retrieval) was developed by integrating the Cognitive Learning Theory (CLT) into the Zull-Kolb learning model.

The "Reflection" phase (green area in the 4R model) is critical because the activation of hippocampal-cortical networks is necessary for successful retrieval (yellow area in the 4R model), as reviewed by Santoro & Frankland (2014), even if the hippocampus may not be involved in the long-term storage of neuronal representations (Hasan et al., 2013).

Without a doubt, the “Review” phase (blue area in the 4R model) is critical to learning because any information that is not properly reviewed cannot be easily retrieved at a later time. That is why a great deal of organization takes place in frontal cortex (blue area in the 4R model), which is clearly a complex and heterogeneous area with strong connections to the other brain regions, as discussed by Zull (2002):

> The front integrative cortex is about the future. It is where we develop ideas and abstract hypotheses. New things appear, and plans are developed here. It is where we organize our thoughts into bigger pictures that seem to make sense. Things are weighed here; it is where we decide to do or not to do something. It is where we take charge (p.37).

Recent research provides further support for the 4R model by highlighting the interaction between the “Review” phase (blue area) and the “Retrieval” phase (yellow area). D'esposito & Postle (2015) described the prefrontal cortex as the “control of controller” and Constantinidis & Klingberg (2016) provided the following summary:

> Human imaging studies and neurophysiological recordings in non-human primates, together with computational modelling studies, reveal that training increases the activity of prefrontal neurons *(frontal integrative cortex in the Zull-Kolb model; blue area in the 4R model)* and the strength of connectivity in the prefrontal cortex and between the prefrontal and parietal cortex *(motor cortex in the Zull-Kolb model; yellow area in the 4R model).*

At this point, it is necessary to note that conventional view of the gradual transfer of elements from one brain area to another has been challenged, as reviewed by Queenan et al. (2017):

> Neuronal representations of a single contextual memory were shown to form simultaneously in the hippocampus and prefrontal cortex. Over time, the *preferred*

retrieval pathway under standard recall conditions shifted from hippocampal to prefrontal engram neurons, resulting in the apparent "transfer" of the memory to cortical circuits even though the representation persisted in both areas.

An analogy to illustrate the preferred retrieval pathway is the new "Quick Access" option in Google Drive as described on Google Blog (2016): "Quick Access shaves 50 percent off the average time it takes to get to the right file by eliminating the need to search for it. It uses machine learning to intelligently predict the files you need before you've even typed anything." That means a regularly accessed file exists in the original folder as well as the "Quick Access" space (Figure 5.15), much like how neuronal representations can be present in both the hippocampus and prefrontal cortex.

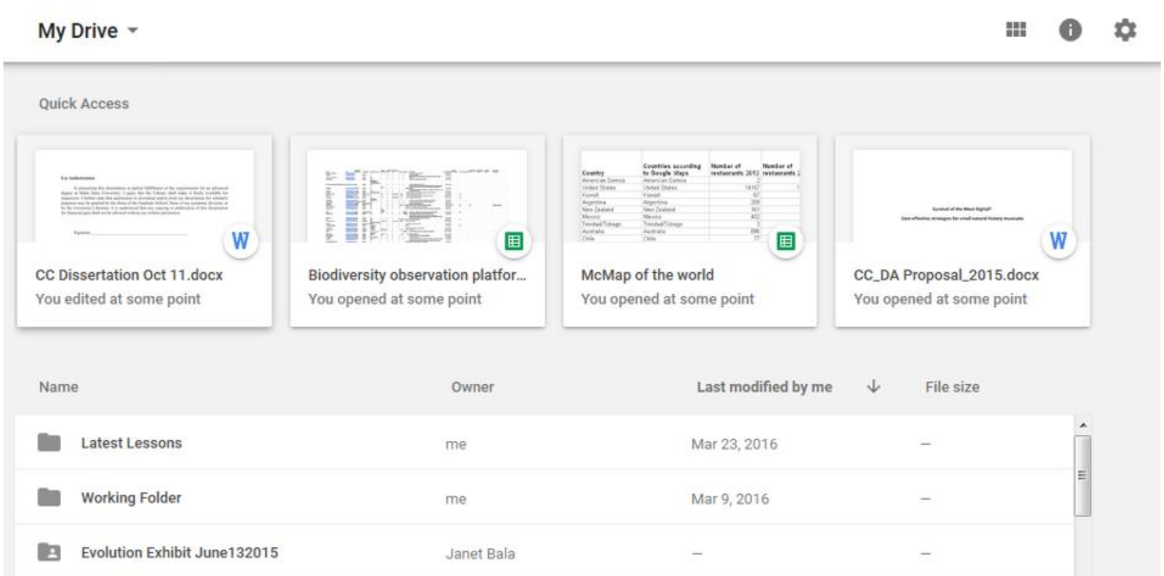

Figure 5.15 The new "Quick Access" option in Google Drive can be used to illustrate the preferred retrieval pathway in the brain.

Applying the Multimedia Design Principles. Every design decision can either enhance or hinder learning, due to the three types of demands on a leaner's working memory during a learning experience (National Research Council, 2013):

1. **Essential processing** of the **intrinsic load**, which is related to the learning goal.
2. **Extraneous processing** of the **extraneous load**, which is not related to the learning goal.
3. **Generative processing** of the **germane load**, which is related to the deliberate use of cognitive strategies.

Next, I will discuss how the multimedia design principles can be integrated into the 4R model using the modified brain-computer analogy, as related to the guiding question: "How to apply evidence-based design principles to the design of interactive learning units?" Although it is possible to argue that every design principle helps with all aspects of learning, that generic approach would not reveal the main strength of each design principle. For that reason, a more selective approach was taken.

1. How to help learners reflect on new information? (Reflection)

Cognitive Load	Processing	Design Principles
Extraneous	Extraneous	Avoid extraneous material (Coherence Principle) Highlight key points (Signaling Principle) Avoid on-screen text that reproduces the complete narration (Redundancy Principle) Place printed words near corresponding pictures (Spatial Contiguity Principle) Present spoken words at the same time as corresponding pictures (Temporal Contiguity Principle)

The "Reflection" phase is activated when the learner pays attention to the information received by the sensory memory. As said, the retention time in this phase is extremely low – mere seconds before it is forgotten. At this juncture, it is easy for the learner to get distracted by extraneous materials. The "Reflection" phase is especially critical in an informal setting because learners have complete freedom to stay in a learning activity or leave. One way to garner the attention of a learner is to reduce extraneous processing by applying certain design principles.

2. How to help learners compare new information with prior knowledge? (Review)

Cognitive Load	Processing	Design Principles
Intrinsic	Essential	Present lesson in user-paced segments (Segmenting Principle) Present key concepts before lesson (Pre-training principle) Use spoken words rather than on-screen text, but not necessarily in all situations (Modality principle)

Zull (2002) speaks of prior knowledge as a physical entity: "It [prior knowledge] builds as brains physically change, and it is held in place by physical connections…They [neurons] make friends easily. They form connections with other neurons… There is a neuronal network in our brain for everything we know" (p.94). During the "Review" phase, learners must identify potential folders that could be related to the new information. This step can be facilitated by design principles related to the essential processing of the essential load (Figure 5.16), which is the amount of essential cognitive required to make sense of the new information (Clark & Mayer, 2016).

Figure 5.16 Examples of multimedia design principles applied: avoid extraneous material (Coherence Principle), highlight key points (Signaling Principle), place labels near corresponding pictures (Spatial Contiguity Principle).

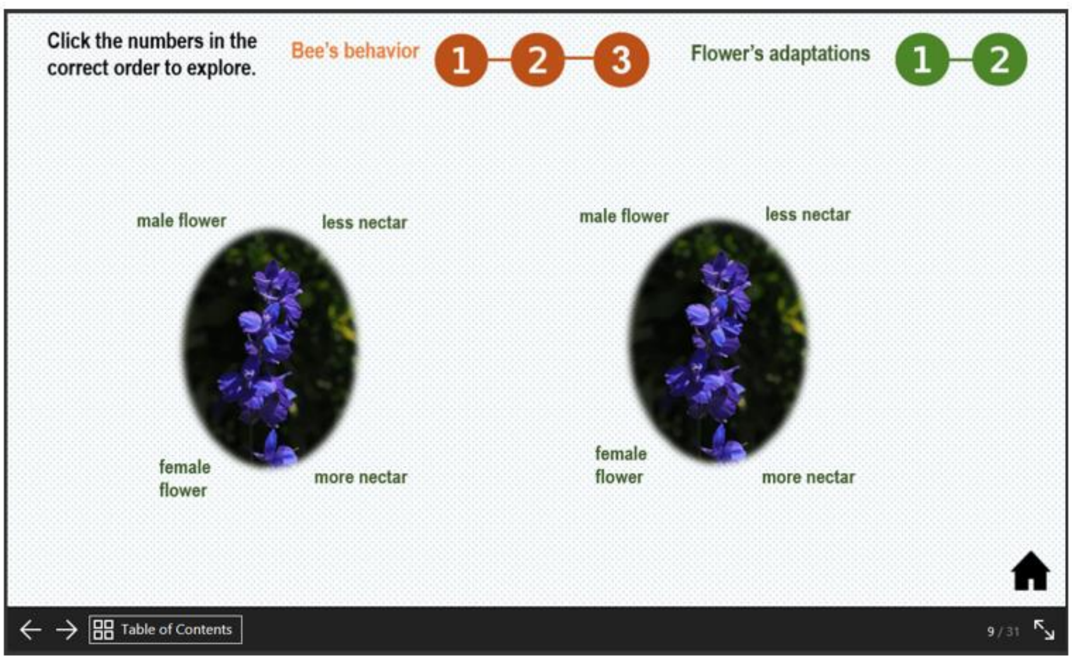

Figure 5.17 In this example, the content is presented in user-paced segments (Segmenting Principle).

The segmenting principle is closely linked to the chunk concept. When learners have control over the flow of information or pace of learning, they can take the time they need to compare the new information with their prior knowledge, without being rushed (Figure 5.17). The pre-training principle serves a similar purpose by introducing key concepts or outlining key terms at the start of a lesson to jog the memory of learners.

The Modality Principle (use spoken words instead of on-screen text) was not applied in this study because the small block of on-screen text on each screen requires very little cognitive processing. However, this principle should be applied when a lot of information is conveyed so learners do not overload the visual channel and underutilize the auditory channel.

3. How to help learners organize new information? (Review)

Cognitive Load	Processing	Design Principles
Intrinsic	Essential	Present lesson in user-paced segments (Segmenting principle)
Germane	Generative	Use words and pictures (Multimedia principle)

Using the modified brain-computer analogy, new information must be organized as files before they are saved into relevant folders in LTM. The role of the segmenting principle is straightforward because small chunks are always more manageable than huge blocks of information due to the limited capacity of WM. The multimedia principle is relevant because learning with words and pictures can facilitate the construction of mental models.

Schnotz (2005) used an integrative model of text and picture comprehension model to explain that after the reception of words and pictures by the visual and auditory channels, both types of information are processed separately by the same subsystems before one mental model that contains verbal and picture information is constructed. Eitel et al. (2013) suggest that pictures serve mainly as a scaffolding tool in the construction of the verbal-picture mental model. This could explain why the multimedia effect is especially prominent in novice learners (Clark & Mayer, 2016), who are at the initial stages of constructing mental models.

While the synergistic effect of learning with text and pictures is widely accepted, it is fitting to mention how the remarkable ability of the human brain to remember picture consistently exceeds our ability to remember words. Grady et al. (1998) explain:

> The superior overall memory for pictures may be mediated by more effective and automatic engagement of areas important for visual memory, including medial temporal cortex, whereas the mechanisms underlying specific encoding strategies appear to operate similarly on pictures and words.

The picture superiority effect may play a role in helping students who learned with decorative pictures that strongly corresponded to the expository text to correctly recall the content one week later (Danielson et al., 2015). Taken together, educators can help learners organize new information by presenting small chunks of text with corresponding pictures.

4. How can we help learners save files in relevant folders? (Review)

Cognitive Load	**Processing**	**Design Principles**
Intrinsic	Essential	Segmenting (Present lesson in user-paced segments).
Germane	Generative	Use words in a conversational style (Personalization principle)
		Use words in human voice instead of machine voice (Voice principle)
		Only add a speaker's image if absolutely necessary (Image principle)

After locating potential folders (Step #3) and organizing new information (Step #4), the learner is now ready to save the files in relevant folders (Step #5). This integration step can be facilitated by the segmenting principle because it takes less time to save smaller files than larger ones. In addition, design principles that aimed to improve generative processing can motivate learners to exert more effort in the learning process. When using narrations, this can be achieved by having a real person speaking in a conversational style (Figure 5.18).

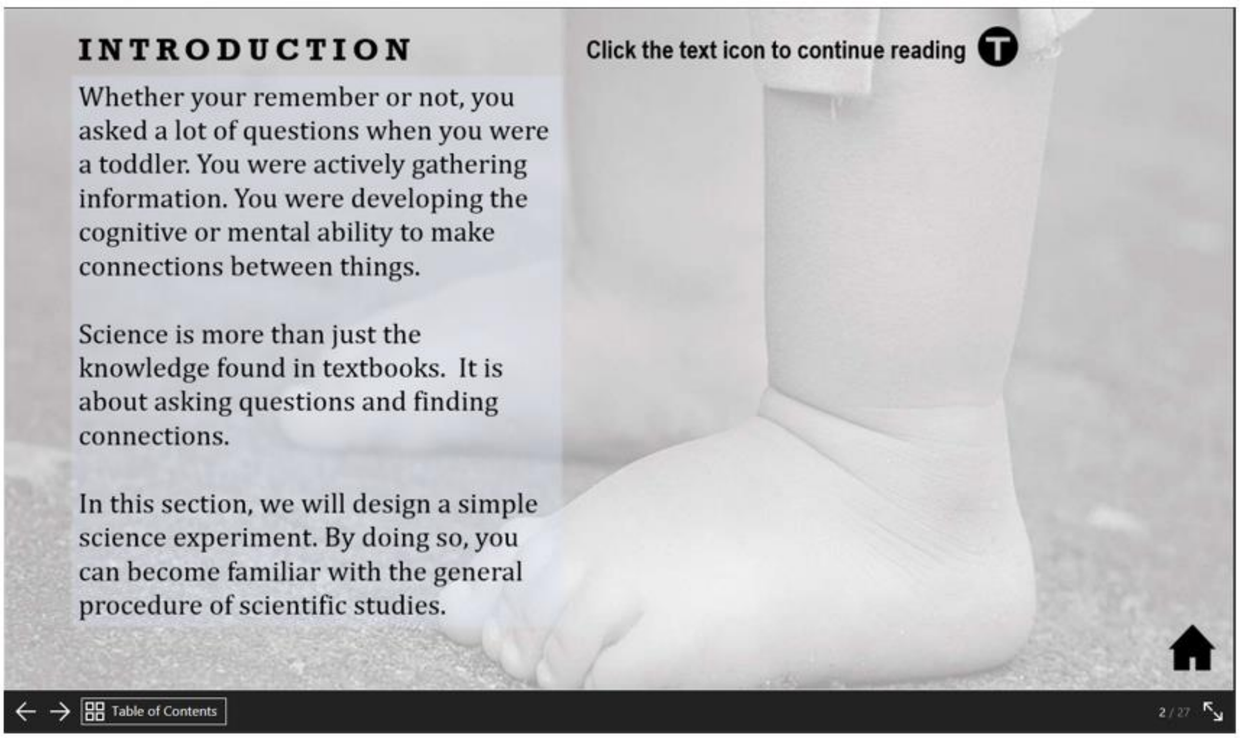

Figure 5.18 In this example, words are in a conversational style (Personalization Principle).

According to Mayer and Estrella (2014), design principles that enhance generative processing serve as "social cues to prime the learner's motivation to exert effort to make sense of the material…conversational style, voice, and gesture may prime a sense of social presence that leads to deeper cognitive processing during learning." In essence, learners are more motivated to make sense of "the represented material through organizing and integrating it with relevant prior knowledge" when the style of presentation gives them a sense of belonging and ownership.

5. How can we help learners save files in relevant folders? (Retrieval)

Assuming that new information has been properly reviewed and saved, retrieval takes place in the parietal cortex or the "yellow" area in the 4R model. There are several theories that explain how the parietal cortex contributes to memory retrieval (e.g., Jaeger et al., 2013) but such a discussion is beyond the scope of this study. In relation to classroom testing, Nelson et al. (2013) used functional magnetic resonance imaging (fMRI) to study neural signals that underlie retrieval practice and found regions in the parietal cortex are specifically sensitive to retrieval practice. In their book, "Make it stick", Brown et al. (2014) devoted an entire chapter to retrieval:

> Practice at retrieving knowledge or skill from memory is a potent tool for learning and retention. After an initial test, delaying subsequent retrieval practice is more potent for reinforcing retention than closely-spaced practice, because delayed retrieval requires more effort. Spaced retrieval produces knowledge that can be retrieved more readily, in more varied settings, and applied to a wider variety of problems.

In fact, even unsuccessful retrieval attempts can enhance subsequent learning. Kornell et al. (2009) presented three explanations for the benefits of the so-called unsuccessful tests:

- The attempt to retrieve the answer may enhance the activation of related concepts.
- Unsuccessful tests may be even better than successful tests at culling inappropriate retrieval routes, making future recall easier.

- Information generated from memory during a retrieval attempt, even if it is incorrect, can serve to cue future recall attempts.

Since neuronal networks are knowledge (Zull, 2002), as long as energy is repeatedly put into a specific neuronal network through retrieval practice, the strength of the network becomes progressively stronger (Goldt & Seifert, 2017). Based on these findings, educators can intersperse assessment items throughout the learning content to provide learners with retrieval opportunities. In this way, there is an input of energy into the neuronal system, whether the retrieval is successful or not (Figure 5.12).

The 4R Model integrated with the A.S.S.I.S.T Framework. Young et al. (2014) reminded educators that meaningful learning requires the interplay of multiple domains, beyond the widely studied cognitive domain. The other domains are affective (i.e., motivation and emotion), social (i.e., interactivity), environmental (i.e., location or setting) and metacognitive (i.e., thinking about one's thinking). Along these lines, learning theories that are explicitly related to basic beliefs about learning can be grouped into at least nine categories (Schunk, 2012): neuroscience, behaviorism, social cognition, information processing, constructivism, cognitive learning, motivation, self-regulation, and development.

Given the complexity of learning at all levels, educators should not be surprised by the many often overlapping frameworks that have been put forward. With a plethora of learning theories, frameworks, and models, it can be overwhelming, to say the least, for educators. To that end, I integrated multimedia design principles into the 4R model that built upon two major learning domains: cognitive and affective (Figure 5.19).

The final version of the 4R model has three components: First, the cognitive model is related to our capacity to learn and was constructed by merging the Zull-Kolb learning model with Cognitive Learning Theory (CLT). Second, the widely used multimedia design principles are derived from the Cognitive Theory of Multimedia Learning (CTML). Third, the A.S.S.I.S.T framework was constructed based on selected research findings related to our motivation to learn, with an emphasis on informal learning.

Based on the 4R model, our motivation to learn appears to be closely related to the visual appeal, the style of learning, the structure of the content, as well as the level of interest (situational or personal) of the learner. These factors combined to draw the attention of learners at the "Reception" phase and possibly help to keep learners engaged. As learners pay attention and move on to the "Reflection" phase, design principles that reduce the extraneous cognitive load can help learners reflect on pertinent information, without becoming distracted by extraneous details. At the critical "Review" phase, design principles that promote essential and generative processing can facilitate the crucial processes of comparing the new information with prior information and organizing the new information for LTM storage.

The process of information retrieval can be promoted by presenting learners with challenges that match the skill levels so learners are rewarded for what they have just learned or already know. That sense of fulfillment, in turn, may motivate them to explore further. Ideally, retrieval should be preceded by learning activities that aid in the organization of new information. Even without using sophisticated software, museum educators can design retrieval opportunities through feedback learning on a platform that is compatible across various devices, thus making learning anytime and anywhere possible.

The 4R model provides a visual representation of how certain design and development principles and recommendations can be applied to facilitate the overall learning process. To a certain extent, the 4R model resolves the dilemma of choosing between a set of principles that mainly focus on our capacity to learn, and recommendations with an emphasis on our motivation to learn. For instance, if I only applied multimedia design principles in this case study, I would have to ignore a major component of informal learning, which is learning for enjoyment. Needless to stay, this model can be further refined; but for the time being, it offers a guide for using evidence-based principles in the design and development of interactive learning units on museum websites.

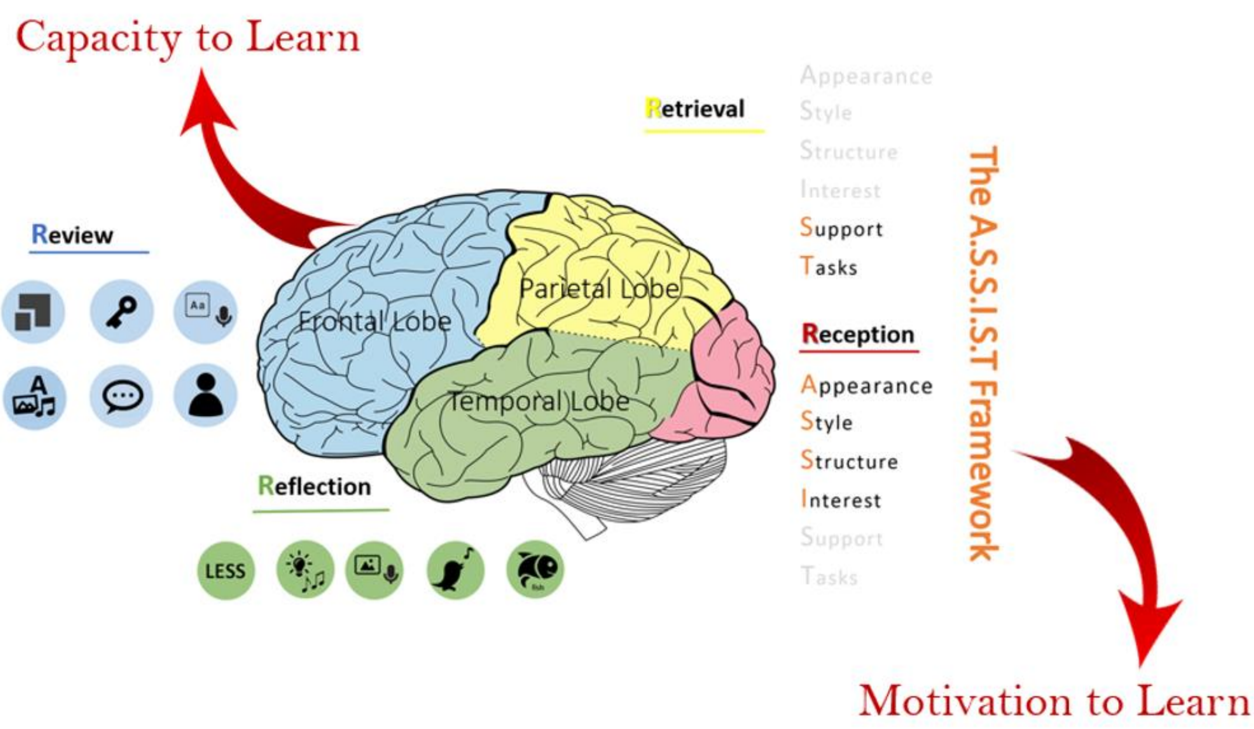

Figure 5.19 The 4R model with four major cognitive phases (Reception, Reflection, Review and Retrieval) is combined with multimedia design principles as well as the A.S.S.I.S.T framework that stands for six design conditions (Appeal, Style, Structure, Interest, Support, and Tasks).

The Outcome

Step #4: Usability Testing

Before deploying the modules to the museum website/public domain, I wanted the opportunity to gather some feedback and make necessary changes. The approval for the usability testing was obtained from the Institutional Review Board (IRB-FY2016-388). According to the U.S. Department of Health and Human Services (n.d.), “Usability testing refers to evaluating a product or service by testing it with representative users. The goal is to identify any usability problems, collect qualitative and quantitative data and determine the participant's satisfaction with the product.” I conducted three rounds of usability testing: formative, summative, and an eye-tracking study.

Formative Testing. Professor Rick Williams and Professor Mike Thomas in the Department of Biological Sciences at Idaho State University agreed to offer optional extra credit points for their students to explore one of the modules. A total of 38 of upperclassmen and graduate students enrolled in BIOL 4417/5517 (Organic Evolution) and BIOL 4442/5542 (Plant-Animal Interactions) completed the Moodle survey with 14 items (Appendix B). Right after the survey responses were collected, I generated a list of names for the instructors so they could assign extra credit points appropriately. After that, I replaced the names of participants with numbers before I reviewed the survey responses.

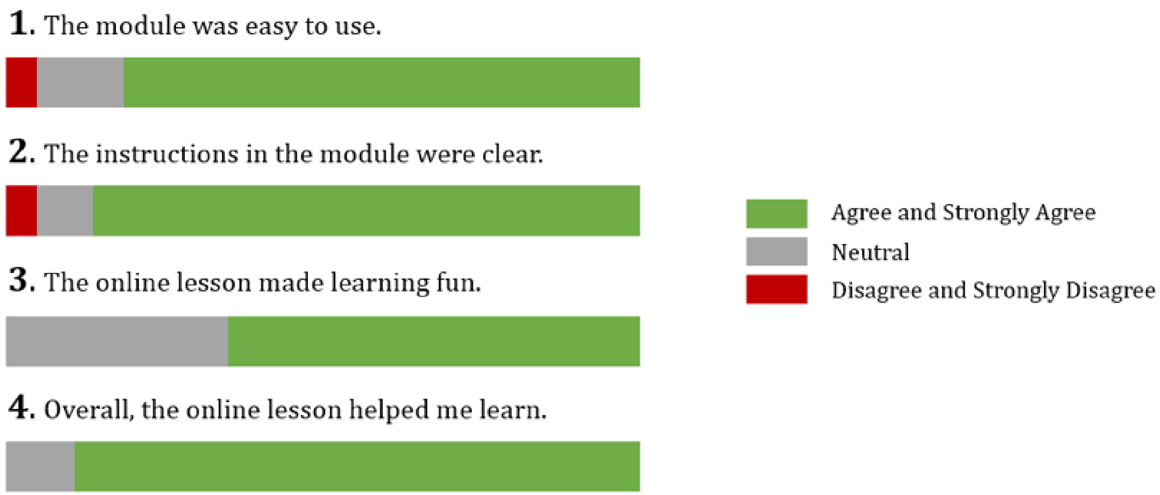

Figure 5.20 Survey responses of study participants (n=38) in the formative usability testing. Survey questions are adapted from Kay (2011).

Less than 1% of the participants considered themselves as beginners in using digital devices. Participants used different devices (i.e., desktop computers, laptops, tablets, and smartphones) on different operating systems (i.e., Windows and Mac) but none reported any compatibility issues. The overall impression of the module was positive, as shown in Figure 5.20. That being said, the survey was not anonymous, so a certain degree of response bias, if any, can be expected because some of the participants are my peers and they are also familiar with the professors involved in the Evolving Idaho exhibit.

In light of the participants' knowledge of basic biological concepts, the professors requested specific feedback on each model organism: burying beetles, rock mice, bees and flowers. For the reason, the bulk of the survey was open-ended optional questions that allowed the participants to share the features that caught their eyes, even if they are already familiar with the topics. The following is a sampling of the comments:

Burying beetles

- *"I think this would be an interesting lesson, especially if you weren't already familiar with size variation in burying beetles*."
- *"I enjoyed the burying beetle video link with Dr. Rosemary Smith. I thought this gave good info and visual support. Also, it is fun to see the burying beetles in action."*
- *"I liked the comparison to cookies. Gave a new way to think about a topic by pairing it with something we already understand. I can't find anything I don't like."*

Bees and flowers

- *"This slide is very well set up to guide the learning ending with a question that solidifies the point. The slide's interactive features are actually beneficial and show us something.*
- *"I liked Rick's video, maybe something from his research could be turned into an interactive figure."*
- *"I liked the part about the flowers adapting and where they had more nectar and the visual illustrations of this."*

Giant Salamanders

- *"This section was very well done. I really liked the map at the first that you got to click on and pictures of the salamanders popped up."*
- *"This one was very good, once again my nephew liked seeing how the salamanders were separate species but still distantly related. The interactive figure was good with this one too."*
- *"I liked the figure clearly displaying the level of speciation achieved by separation of environmental differences."*

Rock mice

- *"I thought the population changes depending on the environment interactive activity was useful."*

- *"The activities were good, my nephew liked predicting which mice would survive."*

- *"I liked the explanation of the changing environment had on the mice color."*

Regarding the relevance of the learning units for museum learning, nearly all the participants agreed the modules are potential supplementary resources for classroom learning, especially for the younger audiences. The following comments from survey respondents are examples that illustrate this point:

- *"The lesson seemed like it may be a better learning tool for younger visitors. College age is a difficult target audience, but my nephew (10 years old) found it very interesting and said he really enjoyed the lesson."*

- *"It would work best for high school students. They have an understanding of science and also prefer technology to the standard museum experience."*

- *It could be implemented as a supplement for High School lessons.*

- *It would be a nice tool to add to a lecture or lesson in order to ensure students had a good grasp of the material. In particular, I think this will be highly beneficial to students who struggle in a lecture setting but learn well in a hands-on-scenario.*

- *Some slides may have been a little too interactive for adults but my children would have enjoyed them.*

- *That it was engaging and had lots of pictures and different ways to engage the user.*

Unfortunately, several design elements that were initially incorporated did not work out as planned and led to some frustrations when participants could not navigate as instructed. This became a major hurdle for me and a major complaint by the participants, yet I was only able to resolve it partially (i.e., users have to click the "next" button twice) because the software was not designed to support such interactivity.

Fortunately, the other critical comments related to design choices could be easily revised and were implemented in subsequent revisions. For example, most clipart images were replaced with high-resolution photographs and all pop-outs were removed. Instead of just listing a few external links for learners to click on, I embedded live pages and video clips. Another important revision was to increase content chunking so there is only one model organism in one learning unit, to avoid the awkward transition from one model organism to another in the same learning unit. I also added more of the popular features – assessment questions and video clips.

Summative Testing. Professor Jack Shurley and Ms. Jennifer Abbruzzese in the Department of Biological Science at Idaho State University agreed to offer extra optional credit points for their BIOL 1101 students to explore the revised module. A total of 43 students completed the online survey with 15 items (Appendix C), which included questions from the Web-based learning tools (WBLT) Evaluation Scale. Permission to use the survey questions was obtained from Professor Robin Kay, who has demonstrated the "good internal reliability, construct validity, convergent validity and predictive validity" of the survey instrument based on large sample size of over 800 middle and high school students (Kay, 2011).

After the survey responses were collected, I generated a list of names for the instructors so they could assign extra credit points appropriately. After that, I replaced the names of participants with numbers before I reviewed the survey responses. Less than 1% of the participants identified themselves as beginners in using digital devices. Unlike participants in the formative testing, participants in the summative testing are not familiar with me or the professors involved in the Evolving Idaho exhibit. In light of that, a lesser degree of response bias, if any, can be expected.

The objective of the summative testing was not to address any knowledge deficiency of the BIOL 1101 students but rather it was for them to review a lesson designed for museum learning. Unfortunately, several participants became annoyed by the non-rigorous approach, possibly assuming it was meant for their own learning and thus evaluated the module from an overly critical viewpoint (e.g., "This is for grade school students!"). The dissatisfaction clearly illustrates an important concept of the Flow Theory – that when skills exceed challenges too much, one becomes bored (Csikszentmihalyi, 1990) and in this case, eventually becoming irritated. This reaction was more prevalent among non-traditional students, as indicated by their self-identified age groups. In hindsight, I should have been very clear about the role of the participants as reviewers, and not as learners. Also, the module was designed for novice learners, not for individuals enrolled in a college biology course.

Fortunately, many participants explored the content as if they were visitors at a physical museum exhibit. The following are sample comments from survey respondents:

- *"I liked being able to click on the different species and getting to know more about them individually. I feel like it kept me engaged and interested in the information that was being provided."*
- *"The vivid images and videos of what people in Idaho are studying".*
- *"Learning about the giant salamanders in Idaho. I didn't know we even had them."*
- *"It was very educational in an entertaining way."*
- *"I like the integration of the YouTube videos as well as the follow-up questions to see what you learned."*
- *"Having to answer questions and retain the knowledge."*

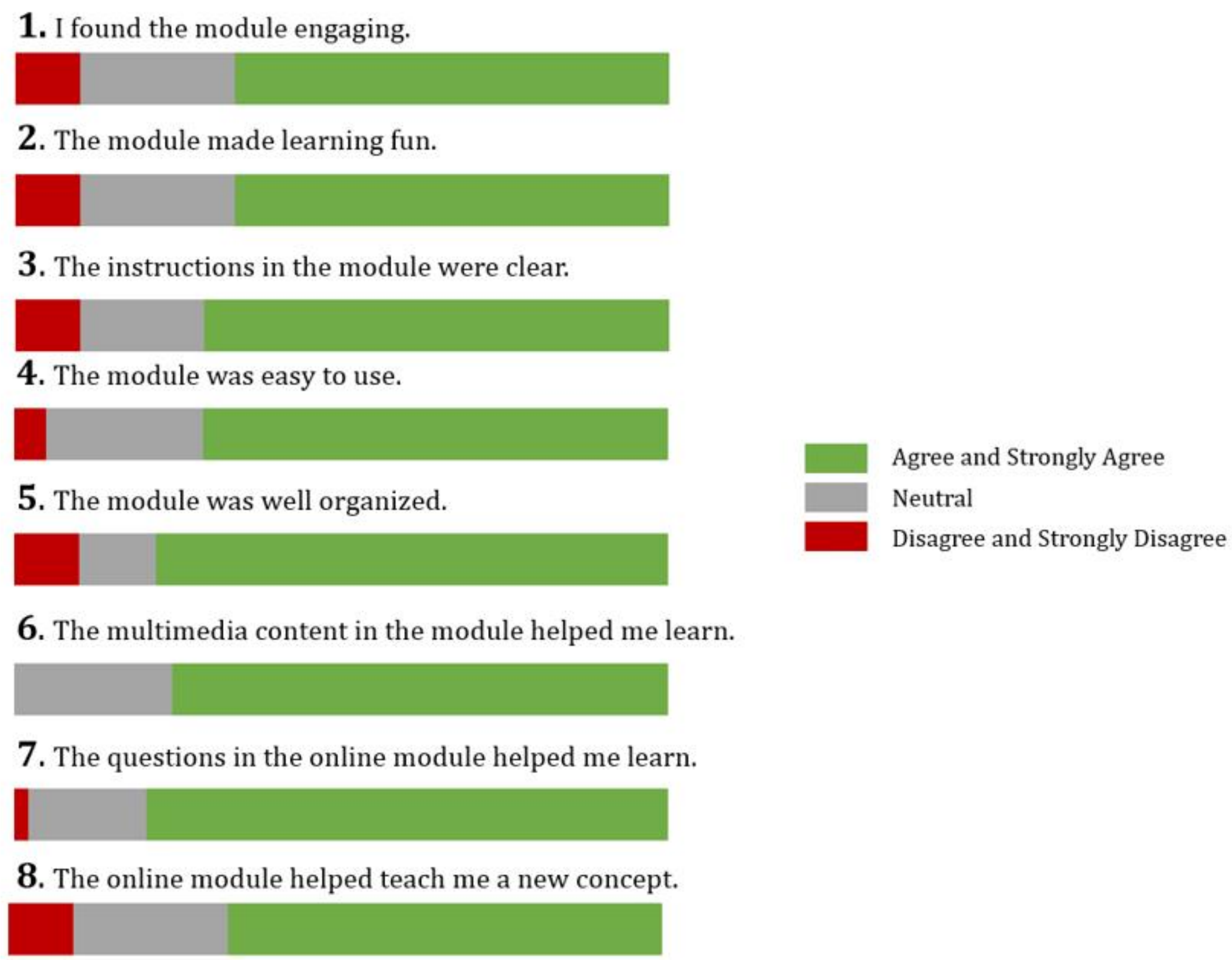

Figure 5.21 Survey responses of study participants (n=43) in the summative usability testing. Survey questions are adapted from Kay (2011).

As shown in Figure 5.21, all survey items received more than 50% of positive feedback (i.e., "Agree" and "Strongly Agree" on a 5-point Likert scale). In particular, participants were especially pleased with the bite-sized content (Item #5) and the assessment tasks (Item #7). Significantly, survey responses confirmed previous findings by Kay (2011) that an engaging learning experience equates fun in learning (Items #1 and 2) and clear instructions make it easier to navigate an interactive learning unit (Items #3 and 4). While around 20% of the 43 participants consistently took the neutral ground for nearly all the survey questions, not a single participant criticized the use of multimedia elements in the learning unit (Item #6).

Eye-tracking Study. The visual appeal strategy I used in my modules is based on the recommendation by Djamasbi et al. (2010) that a main image coupled with a small block of text creates a distinct appeal. To evaluate this design strategy, I used eye-tracking to determine if participants paid attention to the large decorative picture on every screen, compared to the three other screen elements: a small block of text, next and back arrows, and the progress bar. In other words, were learners drawn to the different visual elements on the screen?

Eye-tracking is a very objective research tool because it is very hard to consciously control our eyes. Sauro (2016) calls eye-tracking as something "akin to a lie detector mixed with an MRI." Complex eye-tracking studies are conducted to help researchers understand "the elements that trigger the fundamental brain circuits responsible for attention, cognition, and emotion." As expected, this technology provides an intimidating amount of user data because it supplies a stream of information about the user's eye movement in real time. While eye-tracking can yield a large amount of high precision data appropriate for detailed statistical analyses in quantitative research, it also provides valuable insight in qualitative studies. In fact, one major advantage of the eye-tracking technology is the ability to counter the subjectivity of self-reporting data in many exploratory or qualitative studies (Duchowski, 2007).

Educators can make informed decisions regarding specific design choices because eye-tracking data reveal individual preferences concerning certain design elements. That is why eye-tracking data are incorporated into instructional materials aimed at supporting multimedia learning. Scheiter and Eitel (2016) identified two categories that serve to test and refine assumptions regarding the process of learning with multimedia: "First, eye-tracking is used to study selection and organization processes during learning, and second, it serves to investigate the integration of text and pictures."

Unlike most eye-tracking studies, the objective of this study was not to conclude that Design A is better than Design B, or that participants spent an average of X seconds to complete specific tasks. Rather, the goal of this eye-tracking study is to provide additional evidence on the connection between visually stunning decorative pictures and positive emotions.

Materials and Methods. The approval for this study was obtained from the Institutional Review Board (IRB-FY2016-367). Video-based eye-tracking equipment does not make contact with the eye and is approved as a Class 1 LED device that is safe under all conditions. The eye tracker used in this study is the EyeLink 1000 Plus by SR Research (2017). With the technical support from SR Research, I familiarized myself with the state-of-the-art eye tracker, especially adapting the output to dynamic screens with interactive elements because the EyeLink 1000 Plus is commonly used in studies with static screens (e.g., text, advertisement).

Technically, each dynamic screen could be treated as a static screen or a trial, and thereby many trials can be conducted by just using one learning unit. I decided such an approach would be too disruptive for participants as they would have to press a special key at the start and the end of every test screen to send signals to the eye tracker. An alternative approach is for me to view the gaze behavior concurrently on a host computer and send signals to the eye tracker. This approach also has a downside – the participant may become self-conscious and intently explore every part of the screen knowing that I am following his/her gaze behavior and so, his/her learning preferences may not be revealed.

A typical usability eye-tracking study requires only five participants because five participants can find the same problems as fifty participants (Nielsen, 2012). I recruited graduate students (4 females, 2 males) in the spring of 2017: four from the English department, one recent graduate with a History degree, and another enrolled in the Ph.D. program in Environmental

Engineering. All participants were notified of the study through an email with a flyer, one-page study description, and the consent form (Appendix D).

This eye-tracking study was conducted in the Integrated Lab (B2), located in the College of Business building on the Pocatello campus of Idaho State University. Study appointments are managed by the College of Arts and Letters. Each participant received a compensation of $10 for up to an hour of eye-tracking session. Upon arrival, each participant was asked to read and sign the consent form. Then the participant was asked to complete an online screening questionnaire with eight items on a 5-point scale (Appendix E), adapted from Mayer & Estrella (2014), which serves to "gauge the participants' level of prior knowledge without asking specific questions about the content of a lesson."

I followed the study procedures outlined by Raney, Campbell & Bovee (2014). First, participants were asked to adjust the seat height so they were able to comfortably rest their chin on the chinrest and their forehead against the forehead rest. Next, participants were told about the calibration process where they fixated a set of nine fixation points (black dots) displayed on the monitor at known locations but presented in a random order. Participants were reminded to fixate each dot until it disappeared and try not to predict the next movement of the dot. The calibration process was followed by the validation process, where participants fixated the same nine points as during calibration so the degree of visual error for each fixation point can be calculated.

Once an acceptable calibration was obtained, the participant was asked not to talk because talking causes the head to move up and down, and decreases eye-tracking accuracy. At the end of the session, each participant was shown both the mp4 file with his/her overlaid eye movement and the raw data points. Before leaving, participants completed an online questionnaire with the 10-item Positive Affect Scale (Appendix F) recommended by Um et al., (2012). The scale is derived from the Positive and Negative Affect Schedule (PANAS) introduced by Watson et al. (1988). It is a widely cited questionnaire that asks respondents to indicate the degree to which they experience ten different feelings related to positive effect, using a 5-point Likert-type scale ranging from 1 (slightly or not at all) to 5 (very much).

There are various ways to collect eye-tracking data. The guiding question for this study was: "How much attention was given to the main decorative picture, compared to the arrows, text, and progress bar?" To do so, the following parameters were selected:

- Area of Interest (AOI) – This tool allows researchers to extract data from specific areas of the screen. AOIs can range from a very coarse level (i.e., the text or picture as a whole) to a very fine-grained level (e.g., a word or a detail shown in a picture). In this study, the screen was divided into four AOIs: image, text, arrows, and progress bar (Figure 5.22). To maintain consistency, I modified a regular lesson so every test screen recorded by the eye tracker had the four AOIs. The screens for the introduction, assessment questions, and acknowledgment were not included in the trial. This was accomplished by using the "Hotkey" feature, as advised by SR Research, where each participant had to press the number 1 key before advancing to the first test screen and pressing the number 2 key upon exiting the last test screen. The entire viewing session was recorded by the screen recorder to generate mp4 files. To verify that participants followed instructions, I compared the density of data points. If the Hotkeys are not pressed, the entire viewing session will be included in the trial. In that case, eye movement data for the non-text screens will be included and thus, there will be an excess of data points.

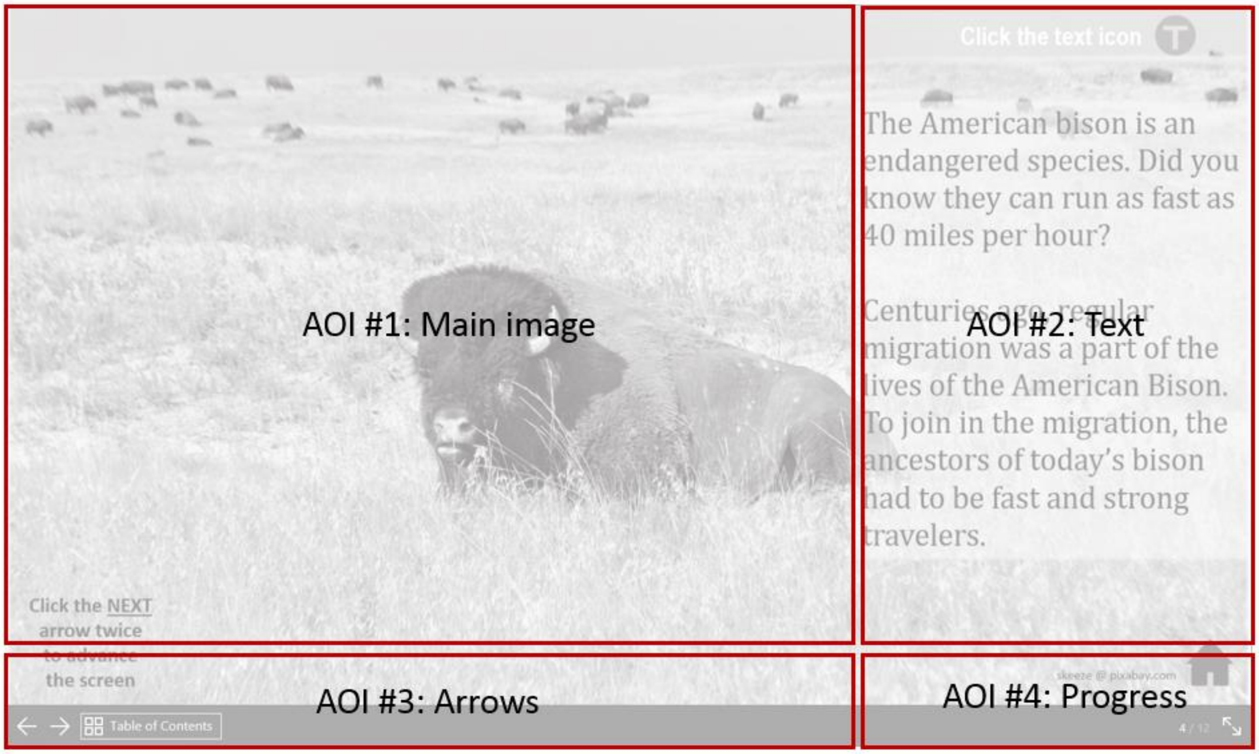

Figure 5.22 The four areas of interest (AOI) used in the eye tracking study: main image, text, arrows, and progress bar.

- Fixations – When a series of gaze points are very close, in time and in space, this gaze cluster constitutes a fixation, denoting a period where the eyes are fixated or locked towards an object. In eye-tracking, a fixation is regarded as a gaze that is maintained for at least 100 milliseconds (ms) or 0.1 second (s). The EyeLink 1000 Plus collects data with a sampling rate of 60 Hz, which means that 60 individual gaze points are collected per second. To determine the amount of attention devoted a certain AOI, the following fixation-related parameters were used in this study:
  - Fixation count – The number of fixations within an AOI, either across the entire trial (total) or only during the first time the AOI was visited (first run).

    - Fixation percentage – Percentage of all fixations within an AOI, either across the entire trial (total) or only during the first time the AOI was visited (first run).
- Dwell time – The total amount of time eye movement data are collected in an AOI. This parameter allows researchers to compare the dwell times between different AOIs:
    - Total dwell time – The total amount of time spent within an AOI during the trial.
    - First run dwell time – The total amount of time spent within an AOI during the first time the AOI was visited.
    - Total dwell time percentage – Percentage of trial time spent on the current AOI.
- Number of revisits – The "Run Count" provides the number of times a certain AOI was entered and left (runs). This parameter reveals how often an AOI was repeatedly viewed.

Results and Discussion. The data points from one participant were not included in data analysis because the individual did not press the Hotkeys as instructed. However, the same participant responded to all the survey questions. Figure 5.23 shows that while all participants identified themselves as computer savvy, not all of them are interested in digital learning (Item #1). However, even individuals who are not intrigued by digital learning appreciated the interactive elements (Item #2). The two participants who rated biology as one of their favorite subjects in high school (Item #3) are not the same individuals who took either an Advanced Placement or a college biology course (Item #6). While all the participants had at least watched a science or nature documentary before, four of them rarely learn science-related topics on the Internet. The selection of non-science students was intentional because the earlier usability testing revealed that some participants with prior knowledge in biology expected more rigorous content.

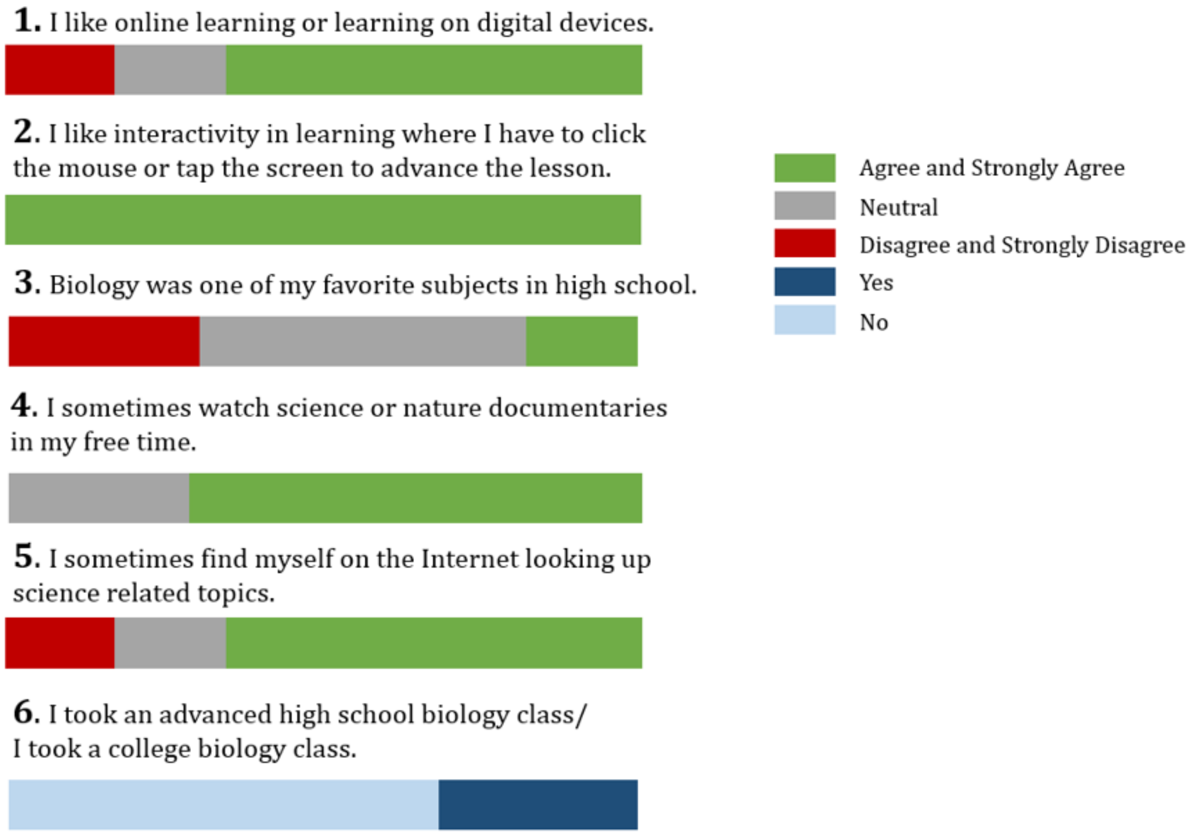

Figure 5.23 Responses of participants (n=6) to the screening questionnaire adapted from Mayer & Estrella (2014) prior to the eye tracking study.

The Positive Affect Scale (PAS) was administered to confirm findings from the earlier usability testing that learning with the module is generally fun. As shown in Figure 5.24, the Positive Effect Scale provides insight into the specific positive emotions that can be associated with the module. The top three self-reported positive emotions (3.85/5) by these participants are interested, alert, and attentive (tied); and the least positive emotions (2.67/5) are strong and inspired (tied).

Figure 5.24 Responses of participants (n=6) to the Positive Affect Scale adapted from Watson, Clark & Tellgen (1998) after their eye-tracking sessions

Considering the non-science background of the participants, it is not surprising that most of them did not feel inspired or confident or excited after spending just a couple of minutes on a learning unit, even if the content was not considered difficult (1.33/5), as shown in Figure 5.25. Based on their responses on the subsequent items in the same questionnaire, it is logical to assume that the positive emotions reported by the participants are related to the visual appeal of the learning unit, which was rated 4 out of 5 stars by these participants. In other words, most participants are drawn to the visual aesthetics of the module, as indicated by the highest rated positive emotions: interested, alert, and attentive.

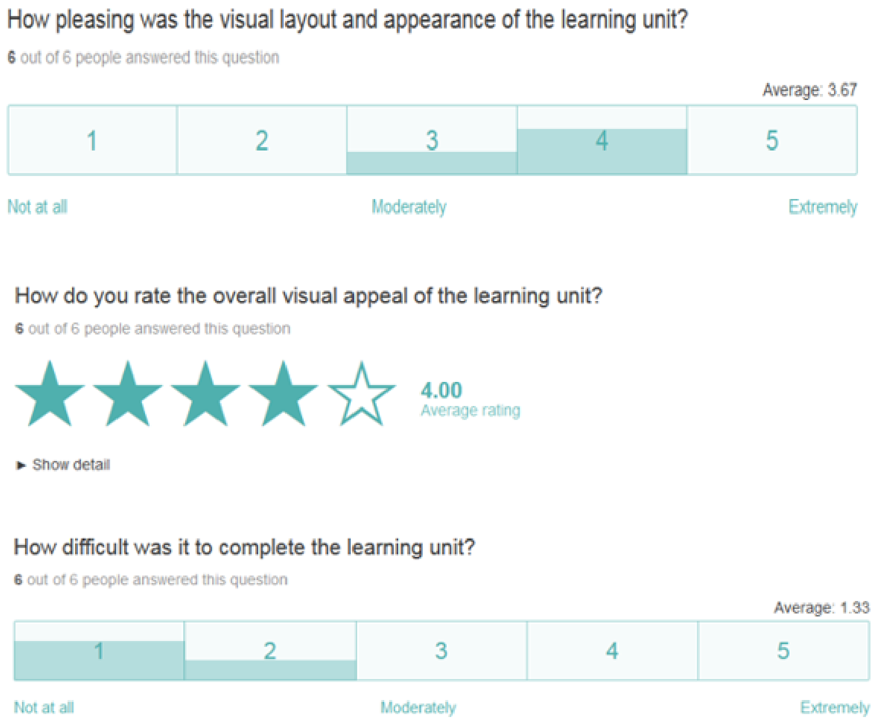

Figure 5.25 Responses of participants (n=6) to survey questions concerning the visual appeal of the learning unit after the eye tracking study.

The usual way to investigate gaze behavior is by means of delineating AOIs, which makes eye-tracking data easier to interpret and are used in various research areas, such as user interaction, marketing research, and psychology. At the point of this writing, there is no consensus among researchers for AOI construction. However, researchers who have applied AOIs with different shapes, sizes, and locations for face stimuli studies have provided recommendations that may be generalized. In particular, systematically increasing the size of AOIs increases robustness to noise for sparse stimuli, but fine-grained spatial effects cannot be uncovered using large AOIs.

In this study, I did not use precise AOIs because the research question was not related to any fine-grained details (e.g., the “back” vs “next” arrow, the bison vs the scenery). Instead, I was only interested in the attention given to the large decorative picture on the screen, compared to the other AOIs. Adopting large AOIs may seem counterintuitive, but Hooge & Camps (2013) pointed out that for sparse stimuli in which there is not much crowding, large AOIs can collect sufficient data for making cross-group comparisons. Hessels et al. (2016) further supported the use of large AOIs for relatively empty stimuli: “If a stimulus were sparse, increasing the size of the AOI would thus mean that more data is included, and differences between or within groups on total dwell time to feature AOIs might be more easily detectable using statistical models.”

The eye-tracking data provided information on the attention given to the four AOIs. By using the parameter “Time to First Fixation,” the sequence of viewing reveals about how quickly participants notice an AOI. However, this parameter was not included in this study because the test module starts with the introduction screens, not the test screens. As a result, participants reached the first test screen at different times.

Although the study was not set up to collect data for each screen, the cumulative data for each AOI provides equally useful information. The parameter “Run Count” refers to the number of revisits. On a static screen, this would represent the number of times an AOI was left and revisited during the trial. On multiple screens, the “Run Count” numbers are higher because the participant had to return to the same AOI on subsequent screens. Clearly, the image was revisited more often than the other AOIs, as shown in Figure 5.26 (B).

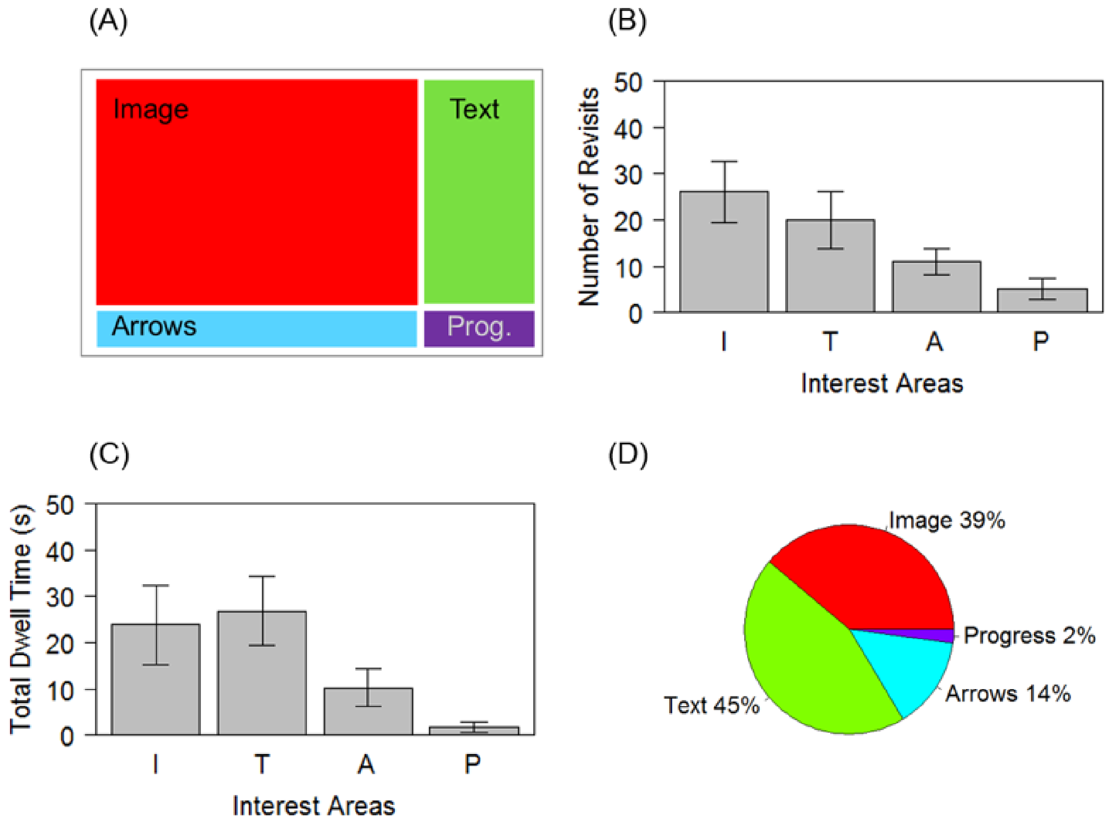

Figure 5.26 Part 1 of eye tracking analysis, n=5: (A) The four AOIs are large main image, arrows, small block of text, and the progress bar. (B) The average time ± SD each AOI was revisited. (C) The average time ± SD participants spend in each AOI. (D) The percentage of trial time participants spent on each AOI.

Since the large image was placed on the left half of the screen, it can be argued that the high run counts for the image AOI are simply the result of general web viewing patterns. For example, Fessenden (2017) reported that "Web users spend 80% of their time viewing the left half of the page and 20% viewing the right half." However, the nearly 50-50 ratio for total trial time spent on the image (left half of the screen) and text (right half of the screen) suggests that more time than expected was spent on the right half of the screen. This finding can be explained by at least two reasons.

First, participants were told about the assessment items at the end of the module (not recorded by the eye tracker) so they knew it was necessary to read the text to answer the questions correctly. Second, the high overall rating of 4 out of 5 stars given by the participants for the visual appeal of the module (Figure 5.25) was corroborated by their gaze behavior (Figure 5.26b). Participants did not gain content knowledge from the image and therefore, did not have to revisit the image to complete the trial. In other words, participants could have gone straight to the text without fixating on the image after the first test screen.

Participants spent a similar amount of time reading the text as they did viewing the image, but less time on the arrows, and the progress bar (Figure 5.26c). This is more clearly illustrated in Figure 5.26d, which shows the percentage of trial time spent on a specific AOI. At this point, it is important to note there were only four test screens and each screen has a small block of text which takes very little time for a native speaker to read. The inconvenience of having to click the "next" arrow twice to advance the screen might have contributed to the greater than expected dwell time on the arrows.

Even more interesting is the fact that participants spent more time on the image the first time they saw it, compared to the time they spent on the text (Figure 5.27a). The parameter "First Run Dwell Time" reveals the total amount of time participants spent in an AOI the first time their eye movement was detected. This may be due to the "Wow" factor of a high-resolution image, which was not present in the other AOIs. The longer dwell time on the arrows could be explained by the instruction placed above the "next" arrow to remind participants to press the arrow twice to advance the screen.

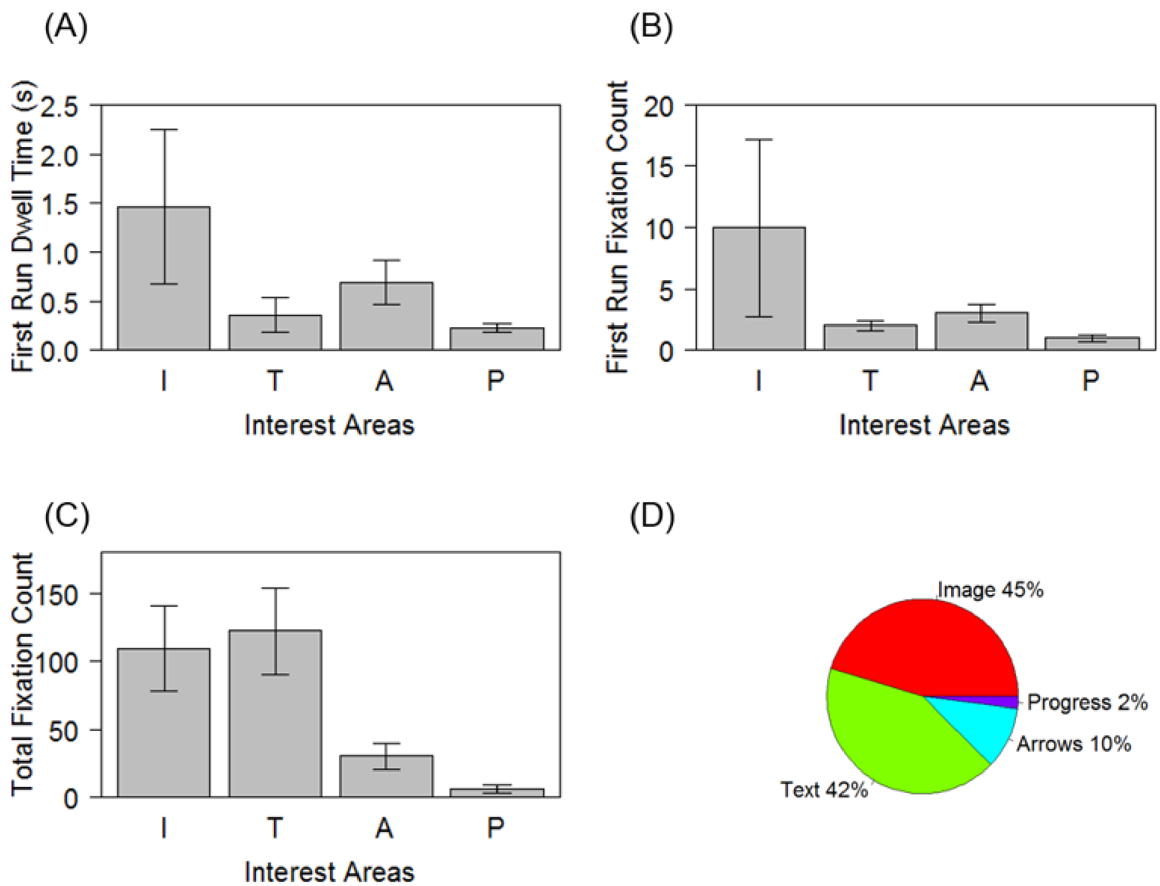

Figure 5.27 Part 2 of eye tracking analysis, n=5: (A) The average time ± SD participants spent in each AOI during the first run. (B) The average number fixation count during the first run in each AOI. (C) The average total fixation count in each AOI. (D) The percentage of fixations in each AOI.

The visual appeal of an interesting image is further supported by the number of fixation counts when eye movement was first detected in an interest area, known as "First Run Fixation Count". Figure 5.27b shows that participants fixated on the image the most the first instant their eye movement was detected in that interest area. This implies that participants explored the main image even on the first run.

Overall, participants fixated more on the text than the other AOIs (Figure 5.27c). This finding is consistent with the fact that participants knew they had to read the text to answer the assessment items at the end of the module. Yet, they also spent some time looking at the image on each screen, even if that was not required for the completion of the learning unit. This is well illustrated in Figure 5.27d that shows the percentages of all fixations in a trial falling in each AOI.

In eye-tracking, higher values generally imply more intense processing, but there are many reasons behind the longer processing time. For instance, learners may find a particular text or instruction more difficult to understand than others. Alternatively, learners may spend more time in an AOI because they find it interesting or at least relevant to the learning task.

In reading research, one way to differentiate the two possible underlying reasons is to calculate the mean fixation duration, a measure typically associated with the cognitive load, by dividing the total dwell time by the fixation count (reviewed by Scheiter and Eitel, 2016). In this eye-tracking study, the mean fixation duration was not calculated because each test screen only has a small block of text that requires very little cognitive processing for adult learners. Similarly, the decorative picture requires little cognitive processing, unlike instructional pictures such as diagrams used in other studies.

In spite of the low sample size and limited parameters used for data analysis, the results confirmed several findings reported in earlier studies. First, the simple design of a main image coupled with a small block of text creates a distinct appeal (Djamasbi et al., 2010). The overall rating of 4 out of 5 stars given by the participants on the visual appeal of the module was corroborated by their eye movement. This preference is similar to that expressed by participants in the earlier usability testing.

Second, attention-grabbing visuals generally cause a more intense emotional reaction than text (Sung and Mayer, 2012). The self-reported positive emotions of being interested, alert, and attentive did not stem from personal interest because this group of participants already indicated their lackluster interest in science prior to the trial. Based on both the eye-tracking and self-reported data, it is logical to conclude that the positive emotions were evoked by the visually pleasing decorative pictures. This finding adds to the emerging evidence of using DP as visual analogies to preserve learning over time (Danielson et al., 2015).

Taken together, the power of visuals should be maximized in resources designed for informal settings because grabbing someone's attention is the first step in motivating the person to learn. Importantly, visuals should be integrated with text and other design elements, as recommended by current research findings, so both our capacity to learn and our motivation to learn can be enhanced.

Step #5: Evaluate (Comparison Study)

To evaluate the modules I designed by applying evidence-based principles using Office Mix® as a practical digital learning platform, I carried out the comparison study with the following guiding question: "How do interactive learning resources developed by an educator at a smaller institution compare with interactive learning resources developed by a team of professionals?"

It is not enough that Office Mix® does not incur any additional cost to the museum, or that educators are likely familiar with PowerPoint®. Unless Office Mix® learning units can provide a comparable learning experience to that found on a commercial platform, museum educators will remain reluctant to explore this platform.

In recent years, a few authors have begun to focus on the evaluation of informal online museum learning. To evaluate design choices for digital learning resources, I compiled an assessment instrument with two components: First, an assessment rubric with key design features, and second, a rating scale of items related to multimedia learning. While these recommendations can be further refined, this instrument serves a practical tool for educators for the time being.

Materials and Methods. The 4-level assessment rubric was adapted from a UX (user experience) assessment rubric for online museum collections by MacDonald (2015). As shown in Part 1 of Appendix G, the rubric is divided into three sections: visceral, behavioral, and reflective factors. The choice of adapting this rubric was based on the similarities between the two museum resources. Both online collections and interactive education units designated for leisure learning, where the pursuit of knowledge is motivated by a positive user experience and not driven by formal assessments. In order to preserve the validity and reliability of the assessment instrument, only a few minor changes were applied to the rubric that was originally designed only for online collections.

The assessment rubric is more appropriate for developing or assessing a set of related learning units, rather than individual units. More likely than not, some learning units would provide interesting facts and phenomena, while others would contain creative elements to engage the learners. It is apparent that highly interactive design features, such as personalization and gaming, can only be implemented with high-end authoring platforms. A possible alternative is to introduce activities that require the learner to collect information from other sources – ranging from visiting an exhibit, a park or a zoo, to interviewing friends and family. The runaway success of the “Pokémon Go" phenomenon has generated many marketing tactics and could inspire future apps that reward participants for locating insect, plants, animals, and even museum artifacts.

The 5-item rating scale for multimedia learning shown in Part 2 of Appendix G was constructed by merging the Learning Object Review Instrument (LORI) by Leacock & Nesbit (2007) and a framework for educational multimedia content by Huang (2005). Both models share many overlapping recommendations for evaluating the quality of multimedia content.

The approval for the comparison study was obtained from the Institutional Review Board (IRB-FY2017-183). Professor Esther Ntuli in the College of Education at Idaho State University and Ms. Janet Bala, the IMNH Life Sciences Collections Manager, helped me recruit participants who have an existing interest in either multimedia learning or museum learning. A total of 19 students participated. The first group of participants was enrolled in EDLT 3311 (Instructional Technology) and received optional extra credit points for their participation. The second group was interns at the Ray J. Davis Herbarium and did not receive any incentives for their participation. Participants were given a print copy of the assessment instrument and were asked to submit their scores online after reviewing the learning units.

For the comparison study, I selected the "Bees and Plants" Office Mix® learning unit on the IMNH website and the "Rock and Minerals" lesson on the website of the Burke Museum of Natural History. Both resources use the click-and-learn type of interactivity to present topics that are not as popular as let's say dinosaurs or charismatic megafauna. While the IMNH module was designed for general learning, the Burke lesson is for elementary school students (Grades 4-6).

To minimize the so-called "order effects", one group of participants was randomly assigned to review either the IMNH unit or the Burke unit first, followed by the Spring Break, before they reviewed the second learning unit. Known as "counter-balancing," this procedure allows researchers to systematically vary the order of conditions so that each condition is presented equally often in each ordinal position (Shaughnessy et al., 2006). This was necessary because "order effects" are of special concern in the within-subject design of this comparison study; that is, the same participants reviewed both learning units and I wanted to compare their responses to both learning units.

Results and Discussion. There are only 18 sets of paired responses because one participant did not review the second learning unit. I used the R statistical software to conduct the paired t-test analysis at a 0.05 confidence level (Table 5.5). The IMNH unit (mean=3.39, SD=0.61) scored significantly lower (*p*=0.03) in system reliability and performance than the Burke unit (mean=3.72, SD=0.57). This is very likely due to the inconvenience of having to click the "next" arrow twice to advance the screen, as highlighted by participants in the earlier usability study.

Table 5.5 Paired t-test analysis of responses (n=18) in the comparison study of Burke and IMNH learning units.

Part 1 (4 possible points)	**Burke (mean) n=18**	**IMNH (mean) n=18**	***P*-value**
Strength of visual content	3.44	3.67	0.22
Visual Aesthetics	3.61	3.56	0.80
System Reliability and Performance	3.72	3.39	0.03*
Interface Learnability	3.33	3.50	0.38
Interface Efficiency	3.28	3.33	0.82
Uniqueness of Virtual Experience	3.17	3.44	0.17
Openness	3.22	3.00	0.21
Integration of Social Features	2.83	2.89	0.85
Personalization of Experiences	3.00	3.11	0.72
Part 2 (5 possible points)	**Burke (mean) n=18**	**IMNH (mean) n=18**	***P*-value**
Learning Goals	4.11	4.28	0.55
Content Quality	4.28	4.44	0.38
Motivation	4.11	3.83	0.33
Multimedia Learning	3.89	4.17	0.33
Feedback and Adaptation	3.50	4.06	0.11

Figure 5.28 provides a visual representation of the scores (4 possible points) assigned to the IMNH and Burke learning units using the assessment rubric. According to MacDonald (2015), the nine factors can be grouped into three categories: visceral, behavioral, and reflective (Table 5.6). The visceral factors help to answer the question, "Will people want to explore the learning unit?" because these factors influence immediate impact/impression. The overall IMNH score for the visceral factors (mean=3.61, SD=0.55) is slightly higher than the overall Burke score (mean=3.53, SD=0.61). The participants preferred the photographs used in the IMNH unit over the clipart images used in the Burke unit, much like the usability study participants. This preference may also be related to the placement of a large image and a small block of text on each screen in the IMNH unit, as recommended by Djamasbi et al. (2010).

Figure 5.28 Comparison of an IMNH Office Mix® unit and a Burke unit by participants (n=18) using an assessment rubric adapted from MacDonald (2015).

The behavioral factors address the question, "Will people be able to explore the learning unit?" because these are factors that influence immediate interaction/usage. Encouragingly, the Office Mix® unit was rated closely (mean=3.41, SD=0.60) to the unit built by a team of professionals for Burke (mean=3.44, SD=0.63). Lastly, the reflective factors focus on the question, "Will people want to come back to explore similar learning units?" because these factors influence long-term interaction/usage. The IMNH unit scored slightly higher (mean=3.11, SD=0.86) than the Burke unit (mean=3.06, SD=0.73). It is important to note that Office Mix® was introduced in 2014 as a digital platform that caters to today's design trends.

Table 5.6 The collective mean values ± SD (n=18) for factors grouped into three categories: visceral, behavioral, and reflective (MacDonald, 2015).

Category	Burke	IMNH
Visceral Strength of visual content Visual aesthetics	Mean (3.53) SD (0.61)	Mean (3.61) SD (0.55)
Behavioral System reliability and performance Interface Learnability Interface Efficiency	Mean (3.44) SD (0.63)	Mean (3.41) SD (0.60)
Reflective Uniqueness of virtual experience Openness Integration of social features Personalization of experiences	Mean (3.06) SD (0.73)	Mean (3.11) SD (0.86)

Using the multimedia learning rating scale, study participants also assigned comparable scores for both learning units (Part 2 in Table 5.5, Figure 5.29). The lower score assigned to the IMNH unit (mean=3.83, SD=0.86) than the Burke unit (mean=4.11, SD=0.90) for the motivation component, which asks the question: "What can I do with the page/screen?" is likely due to the inconvenience of having to click the "next" arrow twice to advance the screen. The slightly higher score given to the IMNH unit (mean=4.44, SD=0.62) than the Burke unit (mean=4.28, SD=0.83) for the content quality component could be because the IMNH content is more interesting to adult learners. Promisingly, the design elements in the IMNH unit (mean=4.17, SD=0.79) offer participants a comparable multimedia learning experience as the Burke unit (mean=3.89, SD=0.76). Lastly, the more advanced assessment features of Office Mix® (mean=4.06, SD=0.80) possibly made feedback learning more engaging than the Burke unit (mean=3.50, SD=1.04).

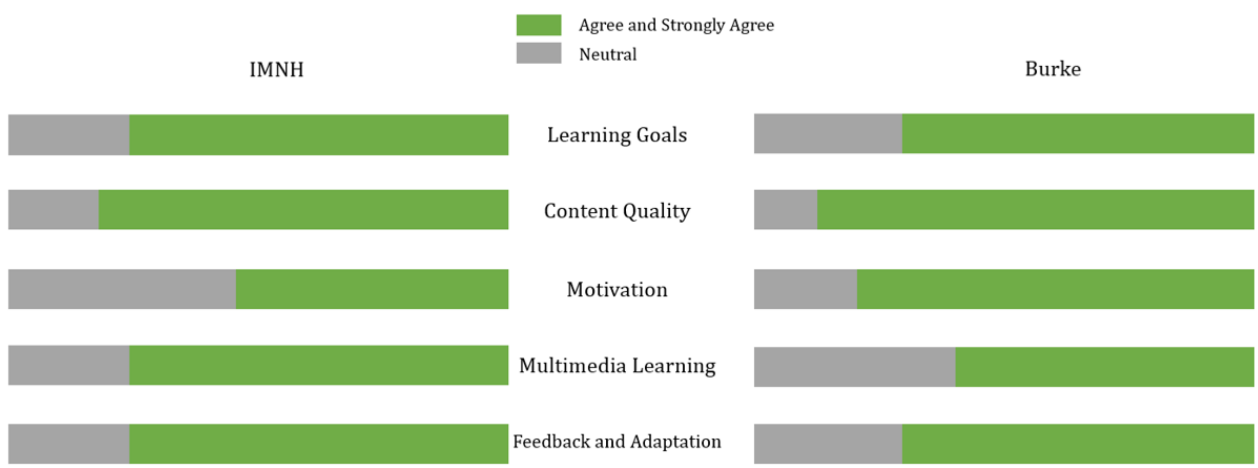

Figure 5.24 Responses of participants (n=6) to the Positive Affect Scale adapted from Watson, Clark & Tellgen (1998) after their eye-tracking sessions

Based on the results, I concluded that Office Mix® interactive learning units are comparable to similar resources developed by a team of professionals. This comparison study can be improved in several ways. Apart from using a larger sample size, the responses from the participants with an interest in multimedia learning and museum learning can be compared. To maintain consistency, study participants should use the same type of digital device. Lastly, it would be ideal to compare two lessons on the same general topic; but that was not feasible at the time of this study due to the limited number of interactives on museum websites.

Chapter VI: Conclusions and Future Directions

Informal learning has gained tremendous recognition in recent years, as highlighted by Johnson et al. (2016) in the *NMC Horizon Report Higher Education Edition*: "As the internet has brought the ability to learn something about almost anything to the palm of one's hand, there is an increasing interest in self-directed, curiosity-based learning." Therefore, organizations with a long history of providing free choice learning are now in a unique position to connect students to new topics outside of their academic focuses.

In the next few years, teaching and learning will likely be a combination of formal and informal learning supported by new digital media, as recommended by Adams et al. (2017) in the *NMC Horizon Report Higher Education Edition*:

> Many experts believe that blending formal and informal methods of learning can create an environment that fosters experimentation, curiosity, and creativity. Solving this challenge requires leaders to articulate its significance and mobilize institutions to integrate informal learning into their curriculum.

Each of the four latest global editions of the *NMC Horizon Report* (higher education, K-12, museum, and library) highlights trends, challenges, and developments in technology or practices that are likely to enter mainstream use within their focus sectors over the next five years. As such, this is a good time for informal learning organizations to explore different digital strategies.

Digital adoption is considered non-negotiable for learning institutions (Adams et al., 2017): "Online, mobile, and blended learning are foregone conclusions. If institutions do not already have robust strategies for integrating these now pervasive approaches, then they simply will not survive." However, the report clarifies that "technology alone cannot cultivate education transformation; better pedagogies and more inclusive education models are vital solutions while digital tools and platforms are enablers and accelerators."

At the same time, increasing numbers of museums are entering the digital learning environment. However, this method of content delivery presents challenges for many museums. According to the Ingraham (2014), the majority of the 35,000 museums in the U.S. are "small, nearly mom-and-pop affairs." Consultants at the Museum and the Web (2015) conference sounded the alarm that "small museums lack all of the new technology platforms and as a result, within 3-5 years most small museums will likely fall further behind the industry and become less relevant to the intended audience."

To the best of my knowledge, this dissertation represents the first systematic approach to explore an effective digital strategy that takes into account the top barriers faced by many museums: limitation in the areas of funding, staff expertise, and staff time (The MacArthur Foundation, 2011; The Pew Research Center, 2013; Arts Council England, 2015). The digital strategy presented in this dissertation conforms to the descriptions given in the *NMC Horizon Report Museum Edition* (Freeman et al., 2016)*:*

> Digital strategies are not so much technologies as they are ways of using devices and software to enrich education and interpretation, whether inside or outside of the museum. Effective digital strategies can be used in both formal and informal learning; what makes them interesting is that they transcend conventional ideas to create something that feels new, meaningful, and 21st century (p.34).

The following are the major contributions of this dissertation:

- I analyzed the websites of nearly 900 natural history museums and science centers in the U.S. to determine the current status of interactives on museum websites.
- I provided a rationale for interactive learning resources on museum websites.
- I pinpointed the characteristics of a practical digital learning platform.
- I reviewed and consolidated selected research findings in learning and design principles originated from non-museum contexts.
- I constructed the 4R model and the A.S.S.I.S.T framework that take into account design choices related to our capacity to learn and our motivation to learn.
- I applied evidence-based principles to the design and development of content available at the Idaho Museum of Natural History (IMNH) by using Office Mix®.
- I conducted formative and summative usability testing on the IMNH modules using surveys and eye-tracking.
- I evaluated one of the IMNH learning units by comparing it with a similar learning unit by the Burke Museum of Natural History and Culture.

Key Findings

In Chapter 2, I analyzed 896 websites of natural history museums and science centers in the United States. The website content analysis showed that most museums (70%) offer information about onsite activities and programs. Only 2% of the entries offer interactive learning resources that can be broadly categorized as either click-and-learn (C) or game-based (G), and most of them are in top one-third of operating budgets within their discipline groups. Thus, most museums have yet to benefit from interactive digital learning on their websites.

Unfortunately, not many efforts have been made to support small museums. In his investigative report, Kaplan (2016a) made it very clear that federal funds are not going to "small institutions with small budgets, which serve small-town residents who have less access to cultural institutions." This website content analysis revealed that nearly 900 natural history museums and science centers in the United States could do much more, if they had access to a practical strategy, to extend their educational roles in this digital age.

Chapter 3 presents the rationale for interactive learning units on museum websites. With the seemingly unstoppable rise of social media as educational tools, interactive learning resources may help set museum learning apart from other informal learning spaces in at least four ways: add to museum online offerings, connect formal and informal learning, motivate learning in bite-sized portions, and repurpose content (Chong & Smith, 2017).

In Chapter 4, I pinpointed three characteristics of a practical digital learning platform that take into account the top barriers faced by museums: essential (budget-friendly, easy learning curve, fast editing approach), supporting (self-assessment choices, design choices, learning analytics), and enhanced (cross-platform compatibility, embeddable Webpages, social media sharing). With a huge number of platforms (devices or software) available in the market, these characteristics can help museum educators with platform selection.

Chapter 5 focuses on evidence-based design and development of interactive learning units using Office Mix®, a free add-on for PowerPoint 2013. This chapter has four sections that discussed the challenges, the opportunity, the approach, and the outcome. The bulk of the chapter concentrated on the approach where I used the widely used A.D.D.I.E instructional design model (Analyze, Design, Develop, Implement, and Evaluate) proposed by Seels & Glasgow (1998). The

“Analyze” step involves the selection of a practical digital learning platform based on the characteristics identified in Chapter 4 as well as content exploration.

The “Design-Develop” steps involved design choices aimed to adhere to our capacity to learn, and those that can enhance our motivation to learn. The former stems from our understanding of the limitations of working memory and the encoding process into long-term memory, which is the premise of the Cognitive Load Theory (Sweller, 1988). In multimedia learning, the cognitive effects have been studied rather extensively in the last two decades, culminating in the widely used multimedia design principles (Clark and Mayer, 2016).

In contrast, design choices related to emotions and motivation have not garnered as much attention until recent years. It is self-evident that all learning has an affective or emotional component, which often refers to a short-term response to external or internal stimuli (Um et al., 2012). Fortunately, museum educators can apply several simple design choices to promote the willingness of learners to interact with the content and take part in learning activities:

- High-quality decorative pictures
- Small blocks of text and suitable colors
- Formative assessment tasks that match skill levels and with immediate feedback

To provide a more cohesive view of the design choices discussed in this dissertation, I first constructed the A.S.S.I.S.T. framework (Appeal, Style, Structure, Interest, Support, and Tasks) to consolidate design conditions that can promote learning for enjoyment (e.g., Lin et al., 2012). Next, I constructed the 4R model (Reception, Reflection, Review, and Retrieval) by integrating the Cognitive Learning Theories (Sweller, 1988), the Zull-Kolb learning model (Zull, 2002), and the multimedia design principles (Clark & Mayer, 2016). Lastly, I integrated the A.S.S.I.S.T.

framework into the 4R model so it covers design choices from two major learning domains: cognitive (our capacity to learn) and affective (our motivation to learn).

The outcome of this case study encompassed the “Implement” and “Evaluate” steps. The formative usability testing (n=38) collected feedback from study participants on the early version of the IMNH modules. The revised version of the IMNH modules was reviewed by study participants in the summative usability testing (n=43). A small eye-tracking study (n=5) served to confirm that a main image coupled with a small block of text creates a distinct appeal, as discussed by Djamasbi et al. (2010). In the comparison study (n=18), participants reviewed the “Bees and Flowers” IMNH module and the “Rock and Minerals” learning units on the website of the Burke Museum of Natural History and Culture using assessment rubrics adapted from MacDonald (2015), Leacock & Nesbit (2007), and Huang (2005).

Taken together, the usability testing and the comparison study provided evidence that several research findings originated from classroom learning can be applied to informal learning in a digital culture dominated by the brief and transient. First, attention-grabbing visuals generally cause a more intense emotional reaction than text (Sung and Mayer, 2012). Second, feedback learning can motivate learners because formative assessment can be designed to meet the three main conditions proposed in the Flow Theory: goals, balance, and feedback (Csikszentmihalyi, 1990). Encouragingly, even minimal interactivity that allows learners to determine when to proceed can positively impact the learning process. Interestingly, more sophisticated forms of interactivity may lack instructional effectiveness (Scheiter, 2014). Instead, low-level interactivity has always been accepted as beneficial to learning even when user control was minimal, such as deciding when to proceed to the next screen (Betrancourt, 2005).

Importantly, participants rated the IMNH lesson as comparable to the Burke lesson, especially when it comes to the strength of visual content, visual aesthetics, as well as the overall learning experience. However, the IMNH unit (mean=3.39, SD=0.61) scored significantly lower (p=0.03) in system reliability and performance than the Burke unit (mean=3.72, SD=0.57). This is very likely due to the inconvenience of having to click the "next" arrow twice to advance the screen, which was already highlighted by participants in the usability study.

Having said that, Office Mix® fulfills all the essential, supporting, and enhanced features of a practical digital learning platform. For museum educators who are already familiar with PowerPoint, Office Mix® is a free tool that requires little or no learning curve. Better still, the built-in assessment choices and learning analytics provide educators with convenient supporting tools. In addition, the freedom to decide the placement of text and graphic allows educators to apply simple visual appeal strategy that combines a large stunning picture with a small block of text. With its cross-platform compatibility, the cloud-based Office Mix® offers an interface that conforms to today's design trends and is, therefore, a serious contender for the more sophisticated but also more costly commercial platforms.

One major limitation of Office Mix® is the lack of navigation choices because every mouse click brings learners to the next screen. I wanted to have at least one interactive item on each screen for learners to explore. However, doing so made it necessary for learners to click the "next" arrow twice to advance to the next screen, which was not well-received at all among study participants. Maybe future versions of Office Mix® will offer educators the option of including multiple interactive items on every screen so the learning process is not similar to clicking on a slideshow. That way, learners will have the freedom to navigate in the order they prefer. Ideally, learners should be able to decide not only when to proceed (interactivity) but what item to explore next (non-linearity).

Study Limitations

In *Surrounded by science: Learning science in informal environments*, the National Research Council (2010) highlighted the importance of assessing learning in informal settings:

> Although informal science settings do not use the same tools to assess learning as schools do—tests, grades, and class rankings, for example—researchers, evaluators, and practitioners are nonetheless very interested in assessing how informal experiences contribute to the development of scientific knowledge and capabilities. The nature of informal settings presents a unique set of challenges in this effort, and the field struggles with theoretical, technical, and practical aspects of measuring learning (p.103).

While it can be very difficult to develop practical, evidence-centered ways to assess learning outcomes due to the characteristics of informal learning environments, I am fully aware that it is critical to have some idea of what one is actually attempting to accomplish and ultimately evaluate. After all, the National Research Council (2009) stated that “evaluation is a process and a tool with which to understand one’s intentions and accomplishments.”

In future studies, I intend to apply the NSF Evaluation Framework for Informal Science Education, which is a set of impact categories that can be used to help guide planning, assessment, and evaluation of projects. The impact categories are as follows with connections to the six strands identified where appropriate (National Research Council, 2010): knowledge, engagement, attitude, behavior, and skills. The six strands of science learning are:

- Sparking interest and excitement

- Understanding Scientific Content and Knowledge
- Engaging in Scientific Reasoning
- Reflecting on Science
- Using the Tools and Language of Science
- Identifying with the Scientific Enterprise

Clearly, not all categories and all strands will be equally relevant to every project, but this framework can help educators with the fundamental questions such as the purposes of assessment and the kinds of learning outcomes that should be considered. In addition, this framework can be further refined to assess learning at the project, group, and individual levels.

Future Directions

A practical digital learning platform can support both museum-generated content and **user-generated content (UGC)**. In this manner, visitors can participate through both the consumption and the sharing of information: "The public should have opportunities to be active participants in the creative processes of the institution" (Clough, 2013, p.63). In fact, participatory experiences inside and outside of the classroom are already a part of the changing tide in the education sector (Johnston et al., 2016). Making such participatory experiences available may help museums to redefine their roles as community anchors, especially for the young people. This concept can be applied to at least two informal learning situations: collaboration with local schools, and citizen science projects.

Blending formal and informal learning

The area of museum visitor participation is growing fast but not without disputes within the greater museum community. Even though open-ended self-expression – where visitors are given a blank canvas – sounds like the ultimate democratic gesture, very few visitors have the confidence to create original content. Museum educators have reported that patrons are more likely to contribute if specific criteria are provided (Simon, 2010). Based on a survey of the literature, case studies, and dialogue with museum educators, the common features of successful museum participatory experiences are online projects that are limited in scope, linked to specific exhibits, and contributed by tightly confined communities who focus directly on their lives and heritage (Govier, 2009). In short, this form of participation can especially connect the museum with the community when the projects have local relevance.

"By the local residents, for the local residents" This can be accomplished through partnerships between the museum and local educators. Digital media assume important roles in the construction of youth identities because digital resources produced by young people are mostly viewed by their peers, as they relish in their roles as both producers and consumers (Weber & Mitchell, 2008). What if students no longer just learn the content to pass a test or an exam, but they use digital media to create student-generated content, which is first peer-reviewed, and then shared on the website of a local museum, in collaboration with the school.

Here is a possible scenario: A group of Pocatello High School students design and develop interactive learning resources using a practical digital learning platform – they can freely choose the topics but there are varying degrees of guidelines from case to case. These resources then go through a peer review process adapted from the process used for journal article submission. Unlike informal learning on social media, this form of participation involves a mix of independence and guidance to ensure quality and consistency. Finally, the resources are made available on the IMNH website. Participants may receive extra credit points or digital badges but more importantly, their contributions are recognized and valued by the community. Over time, the local museum's website becomes a repository of digital content for local students and beyond.

Extensions to Citizen Science

The booming field of citizen science (CS) is mostly fueled by cloud-based platforms such as iNaturalist as well as the popularity of smartphones and their application software (apps). For instance, individuals and find an online CS project, follow the procedures, then submit data directly to an online database and view data collected by fellow citizen scientists.

Basic level: Participation. Most CS projects are designed to collect data for scientific purposes. Participants are generally provided with clear instructions to ensure consistency in data collection so that individuals without a background in science can make a valid contribution to real-life research studies. In that sense, the most basic level of citizen science is participation.

The decision of many casual participants to volunteer in a CS project stems from their initial vague inquisitiveness. Studies found that while many individuals may register to participate, only a small percentage will remain as active contributors. The majority of participants either contribute only occasionally, known as "dabblers" or try out the tasks for a short period of time and give up, known as "drop-outs." One reason that leads to the subsequent inactivity after the "testing the water" stage is uncertainty about the quality of their contribution. Some CS advocates have proposed mini tasks that do not require a major commitment of time or effort, and timely feedback that affirms the value of contribution, no matter how small, to encourage both "dabblers" and drop-outs" (Eveleigh et al., 2014).

One way to enrich the volunteering experience of participants is to offer digital badges for the completion of interactive learning units on museum websites. The combination of bite-sized learning with mini-tasks may be enticing to individuals who have an intrinsic goodwill towards science but are not ready for any sustained commitment. This approach may also provide more structure to the volunteering experience in at least two ways. First, the learning units are self-paced and allow unlimited attempts for any novice to try until he/she has mastered the content; thus, allowing every volunteer to walk away with some sense of achievement. Second, the digital badges serve as tangible recognition of one's determination to achieve higher scientific literacy and thus may motivate a participant to gradually increase his/her involvement over time.

Advanced Level: Production. It appears that people are not motivated solely by technology, but rather by the opportunity to make a difference using technology (Cooper, 2013). Indeed, there is a myriad of ways for seasoned volunteers to contribute to a CS project. Some may become team leaders to assist the research scientists, a few may propose new solutions to unsolved problems, and still, others may help to recruit new volunteers.

Super participants who take pride in their contribution and knowledge acquisition may also be interested in authoring learning units aimed at newcomers. When a practical digital platform is readily available, a mix of both volunteer-generated content and expert-generated content would greatly add to museum online offerings. The collective wisdom of committed volunteers can serve as a source of new topics (e.g., "Things I didn't know about plants" or "Animals I didn't know are found in Idaho"). Just as science communication is increasingly recognized as a responsibility of formally trained scientists, it may ultimately become a crown of achievement for experienced citizen scientists.

Driven by the spectacular growth of digital devices, the nationwide trend of public involvement in scientific exploration will likely continue. One way to enhance the overall volunteering experience is the addition of a structured learning component. The IMNH interactive learning units were designed to inspire a general interest in science and not explicitly knowledge acquisition, making it suitable for participants who are enticed by technology and curious about science. A practical digital learning platform also offers an easy way for seasoned CS participants to document their journey of scientific exploration as well as to engage in science.

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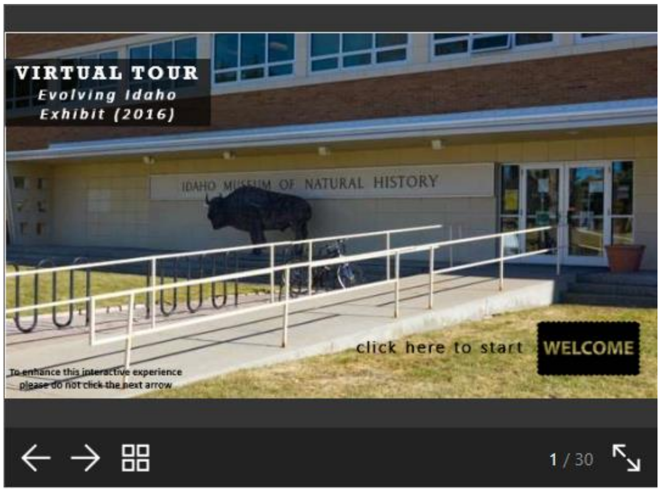
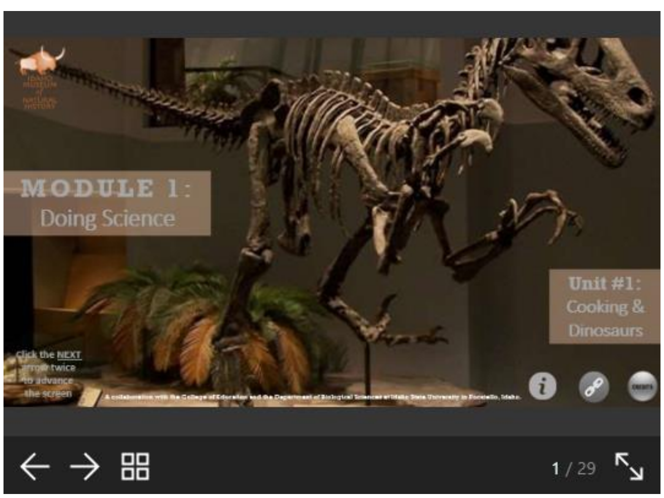
Appendix A: Interactive modules developed using Office Mix®



Evolving Idaho Virtual Exhibit
Number of slides: 30

Meet the Scientists
Number of slides: 11



Module #1: Doing Science
Unit #1: Cooking & Dinosaurs
Number of slides: 29
Assessment questions: 12
Video clips: 2
Learning objectives:

- Explain the differences among observations, inferences, and assumptions.
- Explain the differences between hypotheses and theories
- Understand that fossil records are often incomplete
- Understand that science is based on the best available evidence

Module #1: Doing Science
Unit #2: Finding Connections
Number of slides: 27
Assessment questions: 8
Video clips: 0
Learning objectives:

- Formulate explanations based on evidence (observations and data)
- Understand the general process of scientific inquiry
- Understand that a scientific hypothesis is never proven
- Identify the basic components of a scientific journal article

Module #2: Ways of Nature
Unit #1: Born That Way (The American Bison)
Number of slides: 12
Assessment questions: 2
Video clips: 0
Learning objectives:

- Understand that nature does not give organisms what they want
- Understand that an organism does not try to adapt, but is born with traits inherited from its parents

Module #2: Ways of Nature
Unit #2: Born That Way (The Burying Beetle)
Number of slides: 28
Assessment questions: 6
Video clips: 2
Learning objectives:

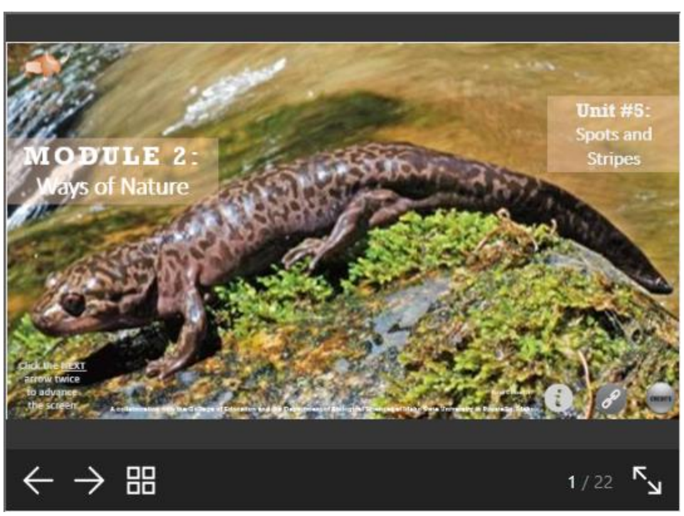
- Recognize that variation exists in every population of every species
- Give an example of how variations can confer a survival advantage

Module #2: Ways of Nature
Unit #3: Born That Way (Rock Pocket Mice)
Number of slides: 20
Assessment questions: 3
Video clips: 1
Learning objectives:

- Give an example of how variations can confer a survival advantage
- Understand how different environmental conditions favor different adaptations (natural selection)

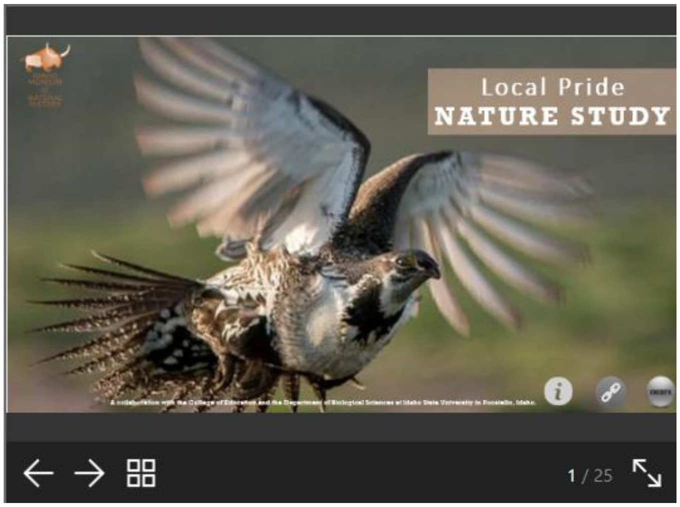
Module #2: Ways of Nature
Unit #4: Special Arrangements
Number of slides: 31
Assessment questions: 9
Video clips: 2
Learning objectives:

- Describe an example of mutualism between flowering plants and their animal pollinators
- Recognize the male and female parts of a flower



Module #2: Ways of Nature
Unit #5: Spots and Stripes
Number of slides: 22
Assessment questions: 4
Video clips: 1
Learning objectives:

- Describe how geographical isolation can lead to the emergence of new species
- Understand how different environmental conditions favor different adaptations (natural selection)



Local Pride Nature Study
Number of slides: 25
Survey questions: 12
Learning objectives:

- Document your observations of the natural world around you
- Identify plants or animals using digital or printed guides
- Collect data on plants or animals and participate in a citizen science project

Appendix B: Formative Usability Testing Survey

Please note that your participation is strictly voluntary and completion of this survey will be regarded as consent. This survey does not require sensitive information from you and therefore, taking this survey does not involve any risk to you.

There is no penalty for non-participation - it will not affect your grade in any way. If you wish to not participate but to receive extra credit, the instructor will provide an alternative means of earning extra credit commensurate with the time and effort required to complete the survey. It is possible to earn the maximum points without answering the optional questions.

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1. (Technology) How would you rate your technology skills compared to your peers?

   Advanced – I know more than others

   Average – I know about the same as others

   Beginner – I am learning how to use technology

2. (Technology) What device did you use to review the online lesson?

3. (Technology) Please include any cross-compatibility issues.

4. (Design) "The online lesson was easy to navigate": Strongly agree, agree, neutral, disagree, and strongly disagree.

5. (Design) "The instructions in the online lessons were easy to follow": Strongly agree, agree, neutral, disagree, and strongly disagree.

6. (Design) "The online lesson made learning fun": Strongly agree, agree, neutral, disagree, and strongly disagree.

7. (Design) "Overall, the online lesson helped me learn": Strongly agree, agree, neutral, disagree, and strongly disagree.

8. (Optional) Please include any comments on using this online museum content as a learning tool.

9. (Optional) Please include at least one feature that you liked and didn't like about the section on burying beetles and natural selection.

10. (Optional) Please include at least one feature that you liked and didn't like about the section on rock mice and natural selection.

11. (Optional) Please include at least one feature that you liked and didn't like about the section on pollinators and plants.

12. (Optional) Please include at least one feature that you liked and didn't like about the section on giant salamanders and natural selection.

Appendix C: Summative Usability Testing Survey

This survey explores the effectiveness of an online museum module in science learning. Please note that your participation is strictly **voluntary** and completion of this survey will be regarded as **consent.**

This survey does not require sensitive information from you and therefore, taking this survey does not involve any risk to you. It will take **less than 5 minutes** to rate the 15 statements.

There is no penalty for non-participation - it will not affect your grade in any way. If you wish to not participate but to receive extra credit, your instructor will provide an alternative means involving comparable time and effort required to complete the lesson and this survey.

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1. What is your age group?

   18-21

   Over 22

2. How would you rate your computer skills compared to your peers?

   Advanced – I know more than others

   Average – I know about the same as others

   Beginner – I am learning how to use technology

   I found the online module engaging - Advanced – I know more than others

   Average – I know about the same as others

   Beginner – I am learning how to use technology

3. "I found the online module engaging": Strongly agree, agree, neutral, disagree, and strongly disagree.

4. "The online module made learning fun": Strongly agree, agree, neutral, disagree, and strongly disagree.
5. "The instructions in the module were clear": Strongly agree, agree, neutral, disagree, and strongly disagree.

6. "The online module was easy to use": Strongly agree, agree, neutral, disagree, and strongly disagree.

7. "The online module was well organized": Strongly agree, agree, neutral, disagree, and strongly disagree.
8. "The multimedia content (images, graphics, and video) in the online module helped me learn": Strongly agree, agree, neutral, disagree, and strongly disagree.

9. “The questions in the online module helped me learn”: Strongly agree, agree, neutral, disagree, and strongly disagree.

10. “The online module helped teach me a new concept”: Strongly agree, agree, neutral, disagree, and strongly disagree.

11. “The online module helped teach me a new concept”: Strongly agree, agree, neutral, disagree, and strongly disagree.

12. What is a difficult concept covered in the module?

13. What is your favorite part of the module?

Appendix D: Eye-tracking Study Consent Form

Using Eye-tracking to evaluate an Online Museum Learning Module

INFORMATION

Your participation will help us evaluate our online museum learning module, which was developed without using an expensive commercial platform. Please read this form and the information sheet carefully to make an informed decision.

PROCEDURES

The study will be conducted in the Integrated Lab (B2) managed by the College of Arts and Letters in the Business Administration Building on the Pocatello campus. In the lab, you will be asked to place your head on a padded chin and forehead rest. While you explore the module on the website of Idaho Museum of Natural History, your right eye will be illuminated with an infrared LED (similar to that used in TV remote controls) from a distance to record your eye movements. Only one visit is necessary and the study session is expected to last up to an hour.

RISKS

We do not foresee any risks associated with your participation in this research study for the following reasons: the infrared illumination is lower than you receive outdoors, the short duration of the study, and the natural protective abilities of the eye.

BENEFITS

There is no direct benefit associated with participating in this study. Indirect benefits may include a meaningful informal online learning experience. Additionally, information from this study may help us learn more about effective multimedia learning using that specific online platform.

CONFIDENTIALITY

Your participation in this study will remain confidential, and any identifying information will not be stored but assigned a code number. Data will be stored securely in a locked office and password protected computers. Any publication related to this study will not make reference to any individuals.

PARTICIPATION

Your participation is voluntary. If you decide to participate, you may withdraw anytime. If you withdraw during or after the session, any data collected will be destroyed.

CONSENT

I have read and understood the above information. I am at least 18 years old, and I agree to participate in this study.

Participant's name and signature_____________________________________ Date ___________

Investigator's signature____ Date____________

*This form was approved by the IRB on June 16, 2016 (*IRB-FY2016-367*).*

Appendix E: Pre-Study Screening Questionnaire

Welcome to this eye-tracking screening test!
It will take you less than 5 minutes to complete this 10-item survey.

1. What is your age group?

   Under 21

   21-25

   Over 25

2. How would you rate your computer skills compared to your peers?

   Advanced – I know more than others
   Average – I know about the same as others
   Beginner – I am learning how to use technology

3. I like online learning or learning on digital devices: Strongly agree, agree, neutral, disagree, and strongly disagree.

4. I like interactivity in learning where I have to click the mouse or tap the screen to advance the lesson: Strongly agree, agree, neutral, disagree, and strongly disagree.

5. Biology was one of my favorite subjects in high school: Strongly agree, agree, neutral, disagree, and strongly disagree.

6. I sometimes watch science or nature documentaries in my free time: Strongly agree, agree, neutral, disagree, and strongly disagree.

7. I sometimes find myself on the Internet looking up science-related topics: Strongly agree, agree, neutral, disagree, and strongly disagree.

8. I took an advanced high school biology class/ I took a college biology class: Strongly agree, agree, neutral, disagree, and strongly disagree.

Appendix F: Positive Affect Scale

This purpose of this survey is to evaluate an online museum learning unit. Please note that your participation is strictly **voluntary** and completion of this survey will be regarded as **consent.** This survey does not require sensitive information from you and therefore, taking this survey does not involve any risk to you. It will take about **5 minutes** for you to rate the **15 statements.** If you decide to participate, you are free to withdraw at any time.

Thank you for your participation!

1. Please indicate the degree to which you experience the following 10 different feelings after exploring the learning unit: Not at all, a little, moderately, very, and extremely.
    a. Interested
    b. Excited
    c. Strong
    d. Enthusiastic
    e. Proud
    f. Alert
    g. Inspired
    h. Determined
    i. Attentive
    j. Active

2. How pleasing was the visual layout and appearance of the learning unit: Not at all, a little, moderately, very, extremely.

3. How do you rate the overall visual appeal of the learning unit? 1 to 5 stars

4. How difficult was it to complete the learning unit: Not at all, a little, moderately, very, extremely

Appendix G: Comparison Study Assessment Tools

Please note that your participation is strictly **voluntary** and completion of this survey will be regarded as **consent.** This survey does not require sensitive information from you and therefore, taking this survey does not involve any risk to you. It will take about **5 minutes** for you to rate the **15 statements.** If you decide to participate, you are free to withdraw at any time.

Thank you for your participation!

Part 1: Assessment Rubric

Visceral Factors

Factors influencing immediate impact/impressions (e.g., Will people want to explore the learning unit?)

	Level 1	Level 2	Level 3	Level 4	Score
Strength of Visual Content	Lack of multimedia elements and content. Images, when present, are too small and low quality. Text is a major distraction from the visual content.	Adequate combination of multimedia elements and content. Some images are too small and/or low quality. At times, text is too dense and distracts from the visual content.	Satisfactory combination of multimedia elements and content. Most images are large and high-quality. Text is used purposefully but some is superfluous.	Strong synergy between multimedia elements and content. All images are large and high-quality. Text is used purposefully but sparingly to enhance the visual content.	

	Level 1	Level 2	Level 3	Level 4	Score
Visual Aesthetics	Color, graphics, typography, and other non-interactive interface elements are used inharmoniously and inconsistently. Multiple errors in spelling and/or grammar. Elicits negative affective reactions.	Color, graphics, typography, and other non-interactive interface elements are moderately harmonious or consistent. Several errors in spelling and/or grammar. Elicits neutral or moderately positive affective reactions.	Color, graphics, typography, and other non-interactive interface elements are mostly harmonious with only minor inconsistencies. A few errors in spelling and/or grammar. Elicits affective reactions that are generally positive.	Color, graphics, typography, and other non-interactive interface elements are harmonious and used consistently. The conventions of writings are followed. Elicits affective reactions that are universally positive.	

Behavioral Factors

Factors influencing immediate interaction/usage (e.g., Will people be able to explore the learning unit?)

	Level 1	Level 2	Level 3	Level 4	Score
System Reliability and Performance	The interface has several serious technical errors that prevent users from completing important tasks. There may be significant delays when loading many pages and/or interface elements.	The interface has some major technical errors that detract from the overall experience but still allow users to complete tasks. There may be some delays when loading some pages and/or interface elements.	The interface has some minor technical errors that don’t detract from the overall experience. There may be a slight delay when loading some pages and/or interface elements.	The interface is fully functional and completely free of technical errors. The pages consistently load quickly and all aspects of the interface respond immediately to user actions.	

	Level 1	Level 2	Level 3	Level 4	Score
Interface Learnability	Interface is not intuitive and requires substantial effort to learn.	Interface is somewhat intuitive but a distinct learning curve is apparent.	Interface is mostly intuitive but has a slight learning curve.	Interface is intuitive and accessible.	
Interface Efficiency	Several major interface elements are hidden and/or unnecessarily complex, which causes major usability issues.	Some interface elements are in unexpected places or are overly complex, causing minor usability issues.	Interface elements require some memorization and/or trial-and-error but are generally easy to use and locate.	Interface elements are easy to locate and easy to use, creating a seamless and immersive interaction between the user and the learning environment.	

Reflective Factors

Factors influencing long-term interaction/usage (e.g., Will users want to come back to explore similar learning units?)

	Level 1	Level 2	Level 3	Level 4	Score
Uniqueness of Virtual Experience	Virtual learning experience is limited compared to the physical learning experience.	Virtual learning experience is directly analogous to the physical learning experience.	Virtual learning experience is different but still borrows from the physical learning experience.	Virtual learning experience is just as substantial/effective as the physical learning experience.	
Openness	The module follows a two-dimensional linear design, similar to a printed textbook	The module follows a minimal three-dimensional linear design. A few screens offer additional information like external links and definitions.	The module follows a moderate three-dimensional linear design. Many screens offer additional information like external links and definitions.	The module follows a non-linear design. Learning is completely self-directed by the users.	

	Level 1	Level 2	Level 3	Level 4	Score
Integration of Social Features	Social tools are not integrated into the collection. No options for sharing or communicating with others.	Social tools are barely visible and/or poorly integrated into the collection. Provides few options for sharing and communicating.	Social tools are present but not prominent. Provides some options for sharing and communicating with others.	Social tools are prominently integrated into the collection. Provides multiple options for sharing and communicating with others	
Personalization of Experiences	Does not allow users to create personalized experiences. Users are entirely passive consumers with no meaningful control over their virtual learning experience.	Allows users to create semi-personalized experiences. Users are mostly passive consumers with little control over their virtual learning experience.	Allows users to create personalized experiences with some limitations. Encourages users to actively influence their virtual learning experience.	Allows users to craft dynamic personal experiences with few, if any, limitations. Inspires users to be active co-creators of their virtual learning experience.	

Part 2: Multimedia Learning Rating Scale

Multimedia Learning	**Rating (1=Low, 5 = High)**					**Comment (if any)**
"Show me what I will learn"	**1**	**2**	**3**	**4**	**5**	
Learning Goal Alignment: Alignment among learning goals, activities, assessments, and learner characteristics						
Content Quality: Veracity, accuracy, balanced presentation of ideas, and appropriate level of detail						
"Why should I care to learn this?"						
Motivation: Ability to motivate and interest an identified population of learners						
"What can I do on the page/screen?"						
Instructional Design or Multimedia learning principles: Design of visual and auditory information for enhanced learning and efficient mental processing						
"Tell me how I'm doing!"						
Feedback and Adaptation: Adaptive content or feedback driven by differential learner input or learner modeling						