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Using Digital Textbooks to Improve Student Learning

Lessons for Military Educators

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Abstract

Interactive digital textbooks designed using learning theory can improve student learning. Professors at the United States Military Academy have been using interactive digital textbooks to improve student learning for multiple years, and their lessons will benefit other institutions. This article describes the difference between interactive and noninteractive digital textbooks, reviews the history of previous learning technologies, and provides a summary of how people learn. Most importantly, the paper discusses how the West Point interactive digital texts were designed based on learning theory and how they were assessed for effectiveness, and it provides notes of caution to other educators seeking to use interactive texts.

In 1913, Thomas Edison said, "Books will soon be obsolete in the schools.… It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed inside of ten years."[1]

Despite Edison's bold prediction, motion pictures never came close to replacing books, and their impact on education—while significant—was far from revolutionary.[2] Since the creation of motion pictures, other technological innovations have been developed. Each time, proponents hailed each innovation as having a revolutionary effect on education; however, each time, these bold predictions failed to materialize, and these technological advances played only "a supplementary means of presenting instruction."[3] Despite being centuries old, books remain among the most pervasive learning tools.

Computers, tablets, and other internet-connected smart devices are the latest technological inventions that may "revolutionize" the education community. However, the question remains: Can they truly enhance student learning? Although it is too early to answer with certainty, data indicate that interactive digital textbooks designed using learning theory can significantly improve student learning.

Over the past several decades, the number of credit hours dedicated to military science at West Point decreased from 8 to 4.5. As a result, West Point's Department of Military Instruction investigated innovative ways to maximize learning and teaching effectiveness. The department's solution was to create a digital military learning environment comprised of interactive digital texts as the foundation for multisensory and integrative instruction, improved interactivity, and asynchronous instructional support systems.

How Interactive Digital Texts Differ from Traditional Texts

As the well-known idiom says, a picture is worth a thousand words. This idiom captures a key concept in which a single image can convey a complex idea; thus, authors have always looked for ways to portray ideas in ways better than words alone. Textbooks have been one of the foundations of instructional techniques since ancient Greece and have been widely available since the invention of the printing press.[4] Just as other earlier technologies, such as the photograph, allow for a picture to replace sketches or "a thousand words" in printed texts, we are currently in a period where authors are experimenting with technology to augment text through multimedia and interaction to enhance learning.

It is important to differentiate noninteractive from interactive digital texts. Digital text is nothing more than a paper book that has been digitized into an electron-

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ic book (e-book). While early research has shown a slower reading rate with digital text, displays have now advanced to the point that there is no difference.[5] Studies also indicate that another perceived advantage of an e-book over its print version is the ability to search for a particular word or words.[6]

Interactive digital text incorporates activities performed "by both the learner and the computer" to enhance the user experience and contribute to long-term retention.[7] In contrast to an e-book, an interactive digital textbook exploits the multimedia and modality principles to enhance learning.[8] The multimedia principle states that images and words used together are more effective than words by themselves.[9] The modality principle states that the use of auditory and visual stimuli together are more effective than only visual or auditory stimuli.[10] The combination of text, visual information, and auditory information all presented within an interactive digital textbook yielded profound improvements in learning versus e-books or other less sophisticated presentations.[11] As opposed to merely flipping or scrolling to the next page, the interactive digital textbook's features allow the reader to select those that best enhance the learning style required for the specific subject. Whereas e-readers and e-books are textbooks on a screen, interactive digital texts make full use of technology to create meaningful learning experiences. Interactive digital texts provide instructional designers with the tools necessary for full lessons to exist in the digital space, supported by similar methods used in the classroom. Multimedia, modality, and interactivity support and reinforce mental schema development and thereby increase cognitive understanding and retention leading to learning transfer.

Technology and Learning

Using new technology to improve classroom learning dates back to the early part of the twentieth century when schools used visual aids, such as films and lantern slide projectors, to enhance classroom instruction. While the use of "visual instruction" greatly expanded in the 1910s, it never came close to making the impact predicted by Edison.[12]

The development of sound recordings, radio broadcasting, and motion pictures with sound in the 1920s and 1930s led to the "audiovisual instruction" movement. Like Edison nearly two decades earlier, "many audiovisual enthusiasts were hailing radio as the medium that would revolutionize education."[13] Despite these bold predictions, the radio has had "little impact on institutional practices."[14] The U.S. military was one of the first institutions to use audiovisual media as primary teaching tools. With the onset of World War II, the military needed to substantially increase its teaching capacity. Lacking time and trainers, the military leveraged technology to produce more than six hundred filmstrips and four hundred training films from mid-1943 to mid-1945.[15]

Television was the next technological breakthrough in the audiovisual instruction movement. In the 1950s, there was an "increased interest in television as a medium for delivering instruction," but much of the interest abated by the mid-1960s.[16]

By the early 1970s, "the terms *educational technology* and *instructional technology* began to replace *audiovisual instruction* as the terms used to describe the application of media for instructional purposes."[17] Computers would become the next technological invention to capture the attention of educators. While work on computer-assisted instruction started in the 1950s, it was not until the development of microcomputers in the 1980s that saw widespread use of computers in the classroom. Soon, proponents once again argued that this technology would revolutionize instructional practices.[18] Renowned professor Seymour Papert argued that the computer would be "a catalyst of very deep and radical change in the educational system."[19] Yet, in the 1990s, the impact seemed to have been quite small. Surveys of American schools indicated that despite having one computer for every nine students, most teachers reported "little or no use of computers for instructional purposes."[20]

With the release of Apple's iPad in 2010, the first widely used tablet, teachers and instructional designers began to reevaluate the usefulness of computers in the classroom.[21] Combining tablets and smartphones with ever-expanding Wi-Fi and cellular networks allowed users constant internet connection and offered new opportunities for learning.

How People Learn

There is no universally accepted definition of learning; however, one that captures the criteria and is widely accepted by educational professionals is "an enduring change in behavior, or in the capacity to behave in a given fashion, which results from practice or other forms of experience."[22]

Constructivist philosophy informs much of the modern learning theory. In contrast to the instructionist view of education popularized in the early twentieth century, constructivism maintains that learning is not memorizing facts or processes but the "active creation of mental structures."[23] The learner creates mental models called "schema" that internalize experiences from the physical world and provide the cognitive basis for knowing as well as future learning. Schemas are built upon and derived from interactions between people, their environment, and the resulting interpretation and internalization of those interactions.[24]

The phenomenological concept of situated cognition is related to constructivist philosophy. This concept posits that people make sense of the world through direct perception of possible interactions with the environment.[25] Situated cognition emphasizes the particular context in which people perceive and integrate stimuli into

their mental frameworks. The experiences are embedded in and influenced by both a person's mental frameworks and the nature of the environment.

These philosophical concepts yielded numerous educational theories and methods. Each varies in its interpretation and application of constructivist thought; however, any learning theory founded on constructivist principles aims to provide learning experiences, which build effective mental models that can transfer learned behavior to application in the real world.

People learn better when they engage in active knowledge construction.[26] Key to knowledge construction is experience and understanding. The interplay of experience, understanding, and reflection drives knowledge construction in modern learning theory. John Dewey states in his seminal work *Experience in Nature*, "Events turn into objects, things with a meaning … [that can] be infinitely combined and re-arranged in imagination … [and are, therefore] infinitely more amenable to management, more permanent, and more accommodating."[27]

David Kolb's experiential learning theory (ELT), one of the best-known modern learning theories, focuses on the process by which experience becomes knowledge. According to ELT, knowledge results from the combination of grasping and transforming experience.[28] The ELT model portrays two modes of grasping experience—concrete experience and abstract conceptualization—and two modes of transforming experience—reflective observation and active experimentation.[29] The modes of the ELT model are cyclical in that the concrete experience creates opportunities for reflection. Students internalize their reflection, building mental models through abstract conceptualization. Active experimentation tests new mental modes that yield new concrete experience. The ELT's cyclical nature allows individuals to build, test, and refine mental models and translate cognitive behaviors into real-world application.[30] The concrete learning experiences that emphasize learning with understanding help facilitate an effective transition from abstract conceptualization to active experimentation.

Just as education philosophy shifted from an instructionist to a constructivist perspective, so too has our understanding of what constitutes important educational outputs. While domain-specific knowledge remains necessary for expertise, understanding how that knowledge is used is also of equal importance.[31] By grounding learning experiences in an applicable context and demonstrating how domain-specific knowledge is used in that context, people are able to build better mental models.[32] Difficult concepts and domain-specific knowledge are even more challenging to grasp if devoid of context. Though it is possible to understand how to apply specific information about a particular weapon or piece of equipment, it is much easier if one comprehends the item's purpose and how it works. Learning experiences that focus on developing understanding as opposed to rote memorization yield more robust mental models that are easier to apply.[33]

The methodologies undergirding the concept of instructional design are experiential learning and learning for understanding. There are countless ideas addressing how best to design learning experiences; however, a few stand out for digital textbooks. The

multimedia principle states that people learn more effectively from a combination of text and pictures as opposed to only text.[34] This concept is not new, as writers have combined text and visuals to enhance connections and improve understanding for centuries. Classroom techniques, such as the use of a whiteboard, also apply the multimedia principle. Multimedia reinforce mental model construction and can provide additional connections not possible with text alone.[35]

The modality principle states that people learn far better from a combination of visual information (text and images) and audio information than from visual information or audio alone.[36] The modality principle manipulates cognitive load by spreading the load between visual and auditory processing channels.[37] The brain processes more information but is not cognitively overburdened because the load is divided. The eventual integration of visual and auditory information enhances mental model building and retention.[38]

Instructional interactivity is defined as "interaction that actively stimulates the learner's mind to do those things that improve ability and readiness to perform effectively."[39] This is not merely being able to manipulate elements of the learning environment, but it instead involves interaction that provides context, a challenge that drives some action or activity, and feedback that provides a means for understanding the action taken and its results.[40] Applying skills purposefully to a simulated or contextualized environment begins the process of active experimentation and testing of mental models built during a given learning experience.

Most theories also share principles that are believed to enhance learning from instruction: "learners progress through stages/phases; material should be organized and presented in small steps; learners require practice, feedback, and continuous review; social models facilitate learning and motivation; and motivational and contextual factors influence learning."[41] These principles correspond to the instructional factors that have been shown to be most important in learning experiences: organization of material to be taught, presenting information in small units that can be cognitively processed, providing opportunities for practice, establishing the provision of corrective feedback, and conducting frequent review sessions.[42] Each of these factors supports the mental model construction and thus long-term retention and retrieval.

West Point's Department of Military Instruction (DMI) applied the theories of learning, the principles of instruction, and current developments in learning technologies to create an innovative new way to teach military students.

West Point's Military Science Textbook

The DMI sought to enhance student learning by developing interactive digital textbooks that incorporate learning science with the latest advancements in instructional technology. This effort produced the Military Science interactive digital textbooks. The

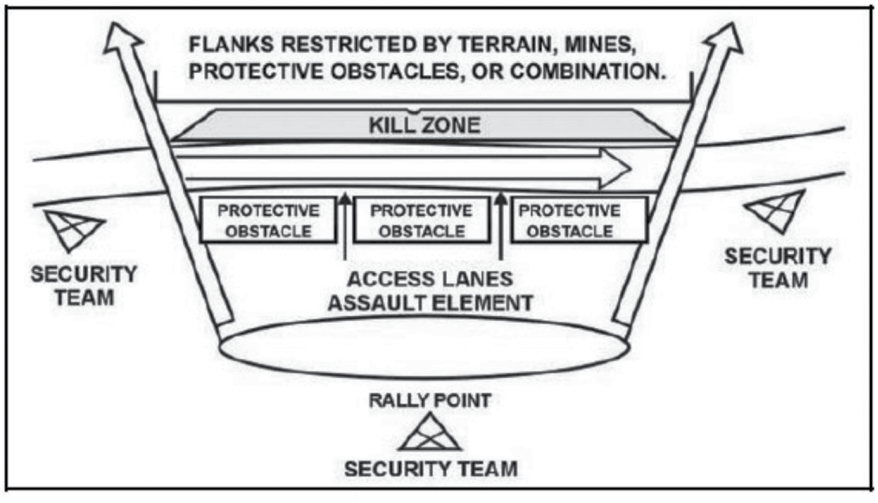
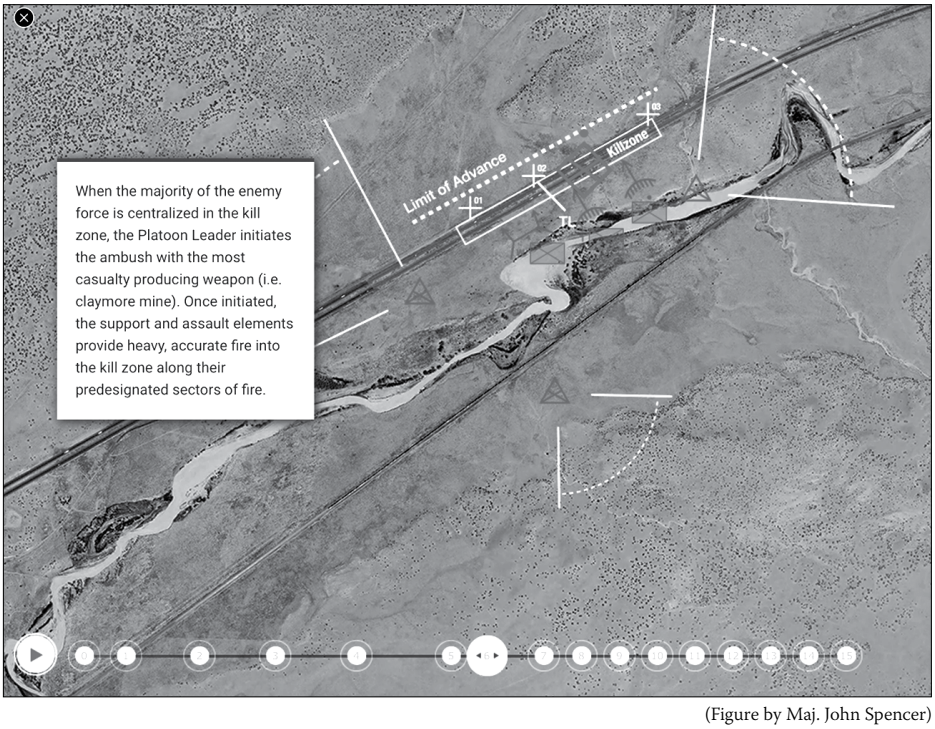
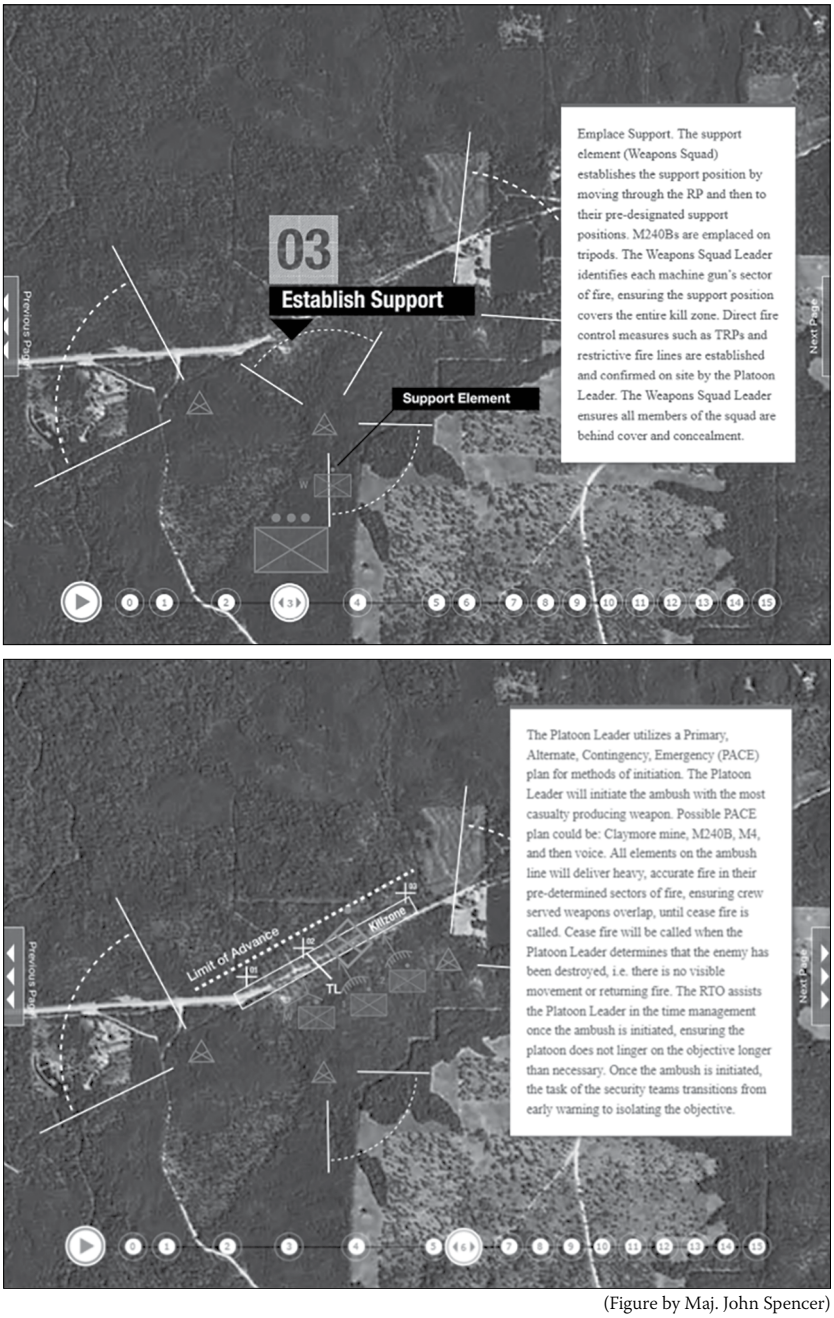


Figure 9-6. Linear ambush.



(Figure by Maj. John Spencer)

Figure 1. Field Manual Image versus Digital Text Image



(Figure by Maj. John Spencer)

Figure 2. Ambush Multimedia Widget

textbooks added multiple interactive features to maximize the effect of multimedia and modality principles and supplement text with assessments and vignettes.

In the past, cadets in Military Science classes (or students throughout the Army) received stacks of field manuals as their primary textbooks. These manuals were not engaging and did a poor job of helping cadets, who possessed little to no experience in the subject, form an adequate understanding of the material. With a mix of knowledge to be memorized (weapons specifications, steps of troop-leading procedures, etc.), rote procedural information (execute a platoon attack, execute an ambush, etc.), and rough illustrations, cadets struggled not only to understand the subject but also to understand what was important and why.

The first step in building an interactive digital textbook was to create an enhanced presentation of text and imagery. The DMI not only transferred all the information from field manuals that was used in the classroom but also provided significant enhancements to maximize the effects of multimedia and modality. Many existing images and diagrams within the manuals were decades old, black and white, and often very poor at conveying the material (see figure 1, page 23). Rather than the picture replacing "one thousand words," it effectively replaced zero. Thus, images and diagrams needed to be wholly redone. Creating quality images was important, as research shows that students learn better by creating the necessary mental models from words *and* pictures rather than words alone.[43]

The next step was to create multimedia and interactive content that takes full advantage of the unique aspects of the digital medium. Examples of different interactives include three-dimensional weapons that can be fully disassembled and assembled; two-dimensional graphics with moving icons (using military symbols) that are played with clicks and finger swipes to depict the ambush, raid, and patrol base; three-dimensional videos of an ambush or patrol base; decision-focused problem sets for tactical missions; vignettes; and interactive assessments.

Mixed-media elements take advantage of the multimedia effect to enhance learning through a combination of text, images, videos, and animations. Learners engage with multimedia content that builds on text, improving connections and explicating complex information in more intuitive ways. The Military Science digital texts stand out in their multimedia design in both their aesthetic, which is uncluttered to reduce extraneous cognitive load, and their function. Learners can control their multimedia experience by manipulating content or maneuver within the interactive text as they deem necessary. Using the sequence bar at the bottom of a widget, such as the one shown in figure 2 (on page 24), the learner can control their interactions to play or replay as desired based on their speed of learning.

Interactive elements in the digital texts supplement multimedia by presenting contextually relevant situations, challenging learners to apply knowledge to solve a problem. As illustrated in figure 3 (on page 27), the learner must choose a course of action and then see how the enemy reacts. Interactive assessments provide in-depth

feedback and structured reflection to support learners as they attempt to integrate new information. Unlike simple checks on learning common in e-learning environments, the Military Science digital textbooks interactives provide detailed feedback based on the learners' choices. Whether they answer correctly or not, learners receive feedback that helps clarify their understanding. Three to five multimedia elements and deep interactives per chapter were built into the Military Science textbooks all supported by updated Army doctrine and core digital functionality like the ability to search, highlight, and take notes.

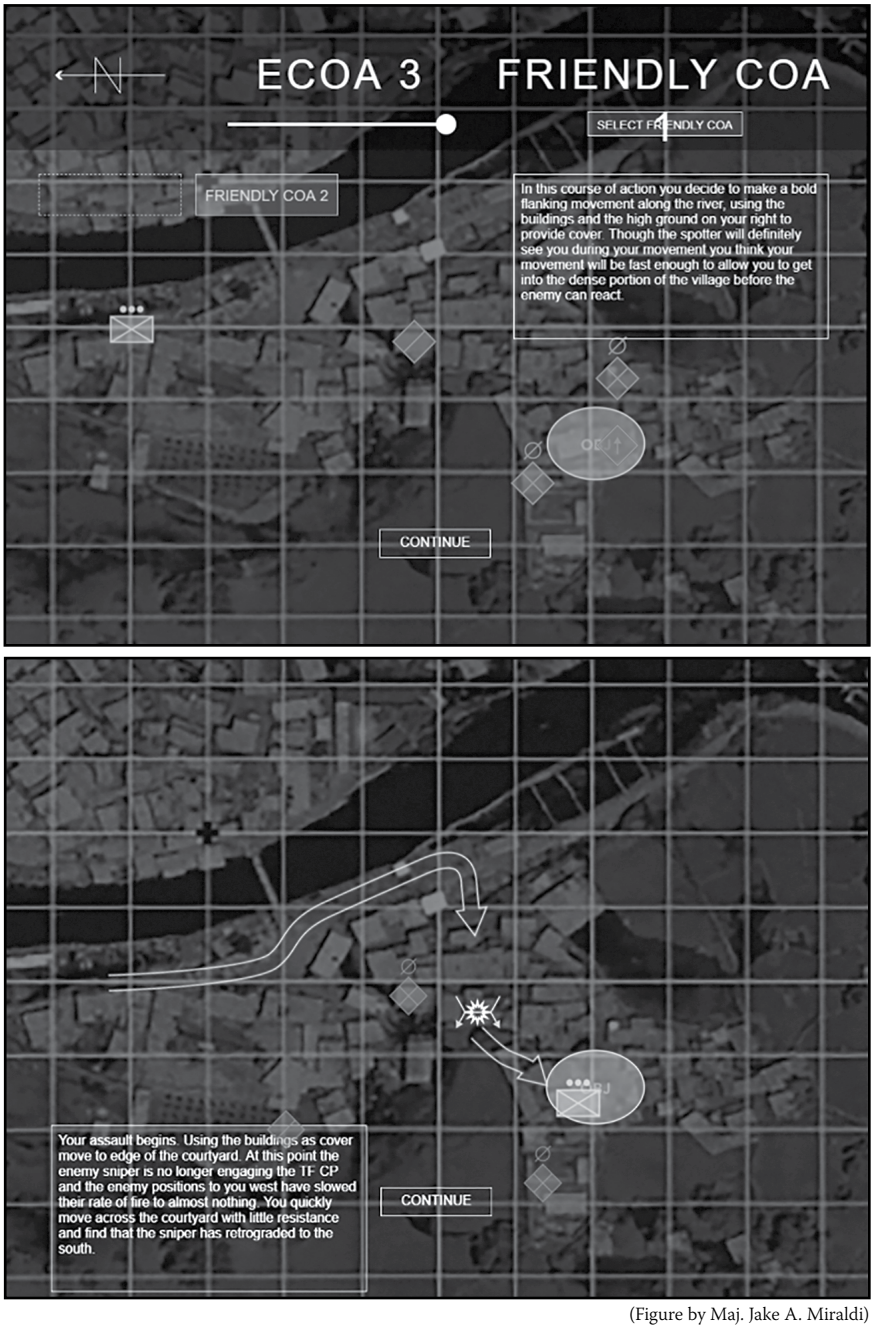
Next, DMI needed to create elements that build on learning from each chapter; specifically, the function to use the new information in real-world settings or problems. The opportunity to use newly acquired knowledge in the Military Science digital texts is a significant difference between it and a noninteractive e-reader or a paper field manual. Interactive elements force learners to use critical concepts from the chapter.

As illustrated in figure 4 (on page 28), learners must choose the correct weapon to engage a target. This interactive digital text provides the reader with the size of the target, the distance to it, and an image showing where it is located on the ground. To choose correctly, learners must recall the information presented earlier in the chapter and apply it to the situation. In this example, the learners will need to apply their knowledge of weapons' ranges and choose a weapon that will be able to place effects on the target at the specified range.

As opposed to merely memorizing a weapon's range, learners are guided to understanding why range matters. Applying the information adds concrete meaning to a weapons range, which contributes substantially to model creation. Similarly, the application starts the process of active experimentation, and it suggests how the future transfer of this information will look.

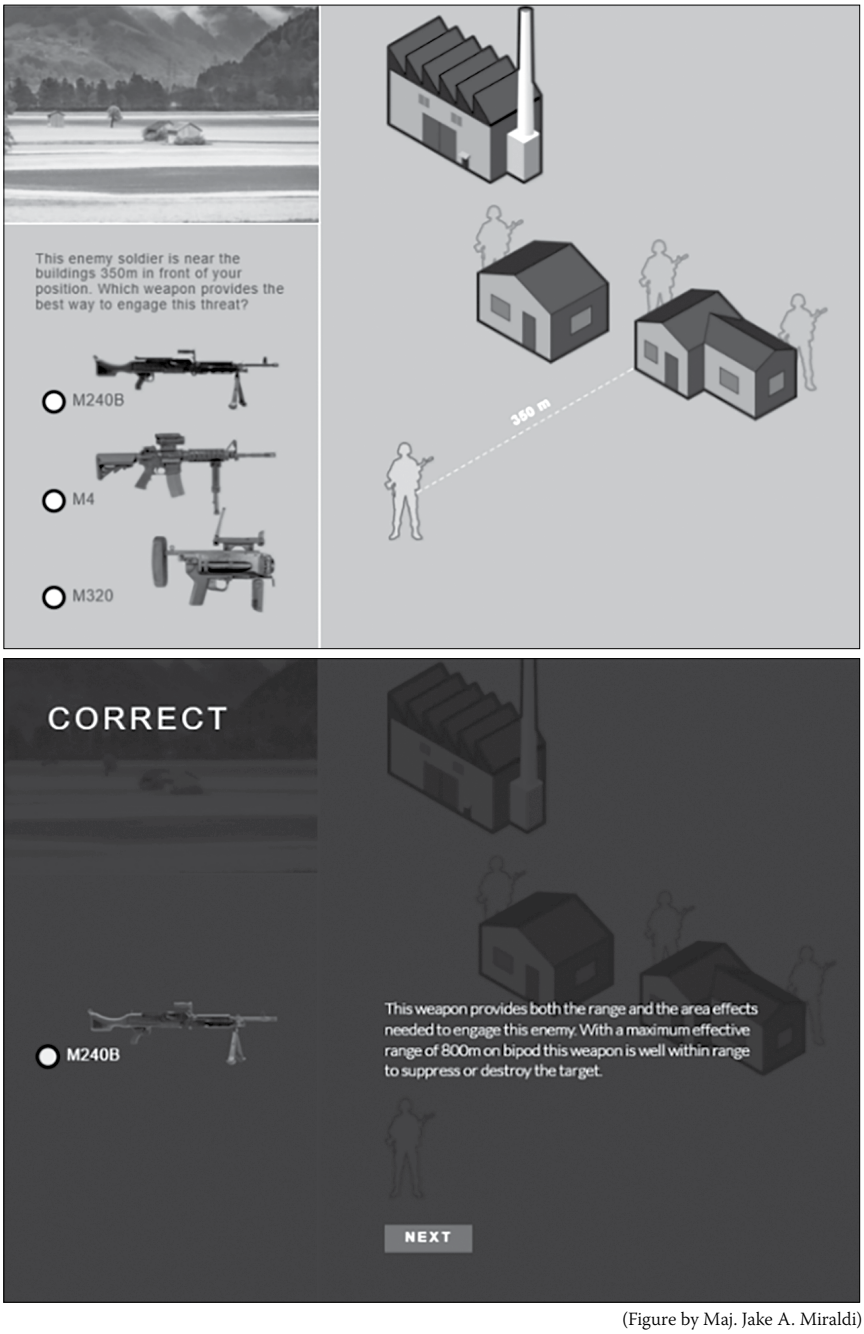
Finally, the DMI recognized the need for learners to engage in reflection as the primary means to integrate new information learned in the interactive digital texts. To accomplish this, multimedia elements and interactives were designed to offer the learner opportunities for guided reflection (shown in figure 5, page 29). In many widgets, learners are asked to reflect on the multimedia presentation or the interaction they have just experienced by answering guiding questions. These questions build on each chapter's learning objectives and help to organize and contextualize recently learned information. The interactive digital texts capture a cadet's guided reflection and allow instructors to recontextualize, reframe, or reinforce student's thoughts on the material both as a means to ensure correctness and as a fluid entry or reentry into key lesson objectives.

The Military Science digital texts are designed to provide meaningful and memorable experiences based on core military competencies, including weapons, planning techniques, and tactics. The integration of authentic environments, problem-solving, and simulations, as well as a focus on the implications of the instruction to a cadet's life and a future career, collectively contribute to improved learning. Each module puts the learner in a particular context that simulates the real-world situations where that knowledge might be



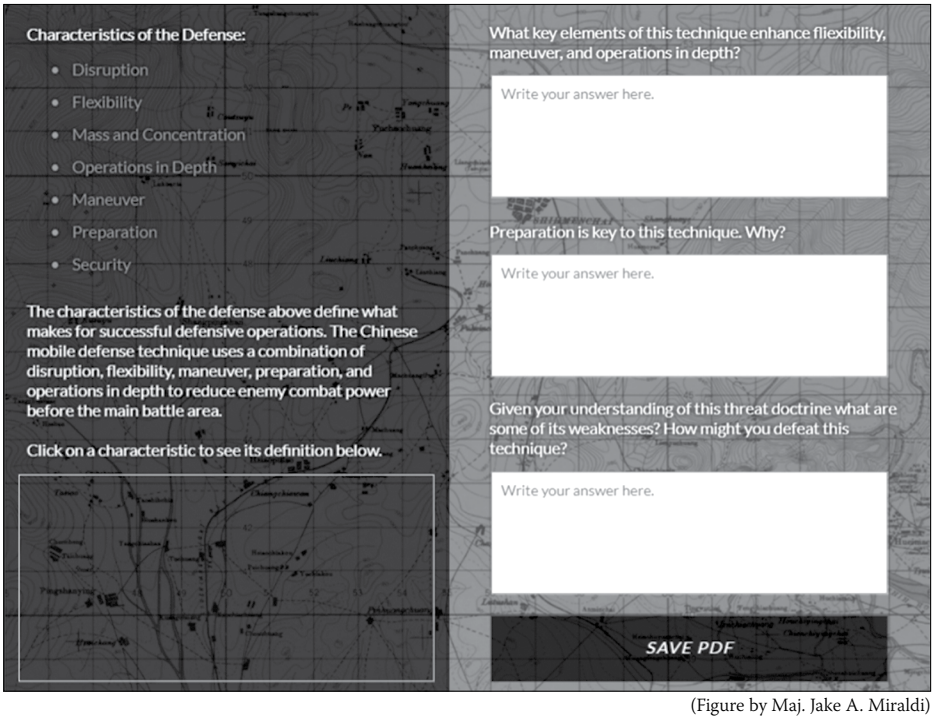
(Figure by Maj. Jake A. Miraldi)

Figure 3. Barg-e Matal Vignette Interactive



(Figure by Maj. Jake A. Miraldi)

Figure 4. Interactive Assessment



(Figure by Maj. Jake A. Miraldi)

Figure 5. Guided Reflection

used. Through situated cognition, learners not only recognize the real-world implications of what they learn but also retain the information better. The goal was to develop learning with understanding to allow for the use of information instead of simple facts.

Digital Textbooks That Can Support Teaching Pedagogy

By using the DMI interactive digital textbooks as a foundation for a digital learning environment, military educators are able to teach more pertinent information, enhance retention through mixed-method learning, and engender greater student commitment, motivation, and understanding. When students experience military knowledge and principles applied in context, they are better able to integrate that experience and carry the knowledge forward to their next learning experience.

The interactive digital textbooks provide instructors with a standard textbook across the Military Science curriculum and the means to facilitate and enhance classroom instruction. Through digital text modules built on instructional design principles, cadets better understand the core tenets of what they learn and arrive in class better prepared

to engage with the material in a more nuanced way. Since cadets who use the interactive digital textbooks have higher rates of initial understanding than those using traditional textbooks, instructors may choose how to teach their class to reinforce that understanding. Instructors may also use more sophisticated teaching techniques like project-based learning or other applicative instruction to provide additional context to the knowledge gained while using the digital texts.

The interactive digital textbooks also provide instructors with visuals, vignettes, and other content or functions. Because it is currently available on any operating system with an internet connection, instructors are able to project content from the digital textbooks onto a screen in class to review information, access an out-of-class reading, or serve as the basis for in-class instruction. As the interactive digital textbooks and the digital learning environment continue to expand, more and better options will be available for instructors to incorporate into their lessons. Instructors will have access to more vignettes, both historical and more recent, as well as playable scenarios and other interactive content that can provide engaging primers to instruction or the foundation for classroom instruction itself.

Instructors can take advantage of these resources to incorporate real-world applications into their courses, a strategy that promotes learning and long-term retention.[44] For example, a video interview with a combat medic from a well-known battle at the end of a medical tasks lesson can provide learning benefits.

By facilitating different types of instruction, the interactive digital textbooks allow instructors to experiment with more nuanced and improved teaching methodologies. Instructors will not have to spend significant preparation time in creating learning experiences from scratch and instead will have that time to build better lesson plans based on reliable, interactive content. The combination of improved learning outside of class and improved instructor flexibility in class will yield engaged and motivated students and instructors.

Assessing Digital Textbook Effectiveness

Though the literature on the overall effectiveness of interactive digital textbooks across the field is fairly limited, the existing quantitative and qualitative data has shown that using digital textbooks can significantly improve learning.[45] In particular, Amanda Rockinson-Szapkiw et al. highlighted improved levels of psychomotor and affective learning among university students through the use of digital textbooks.[46] Other studies show improved vocabulary development in younger students and support digital textbook use in an elementary school environment.[47] Hyunsun Kim and Eunyoung Suh found that in a nursing school context, students improved more quickly and retained information better through the use of a mobile phone-enabled application.[48] West Point's internal data on the effectiveness of digital textbooks also bears out its effectiveness and gives credence to its digital textbook methodology.

In 2012, West Point's History Department introduced its interactive digital textbook that was developed for its military history course. West Point has been teaching military history since 1818 and has data on its "History of Military Art" course dating back to 1969. After introducing its interactive digital military history textbooks, the number of A's in the course increased by 46 percent.[49] Through surveys, 84 percent of cadets "agreed or strongly agreed [that] the new interactive e-book made the course more interesting" and "67 [percent] agreed or strongly agreed [that] the interactive e-book led them to read more and made learning easier."[50]

The digital Military Science texts were only recently implemented; therefore, there is currently a lack of sufficient data to show a statistical change in student performance, but cadet surveys and qualitative feedback by instructors demonstrate a similar promise. Through end-of-course assessments, cadets have explicitly highlighted the interactive digital textbooks' influence on their overall learning. On cadet surveys, 64 percent of cadets agreed or strongly agreed that the interactive digital texts were useful learning tools.[51] Cadets highlighted the texts' structure ("[It] was laid out well and useful in doing OPORDs [operation orders]"), accessibility ("Sometimes it's better to have a hard copy but being able to have it along with you on an electronic copy is very helpful and better than a big book of references"), and content ("[It] allowed me to watch an interactive video on conducting a platoon attack as well as a platoon ambush. This helped on my [test] as well as the final OPORD") as particularly useful to their overall understanding in the course.[52]

The digital Military Science texts also enabled continued learning in a field environment. By using ruggedizing tablets, the textbooks were used to support field instruction where the advantages of multimedia learning were not an option previously. The texts also reinforce experiential learning during downtime between repetitions or field exercises.

Ultimately, the design of lessons within the interactive digital texts using the suite of potential multimedia, assessment, and guided reflection functions are what makes them so powerful. Functionality within the texts make them more like classroom instruction than simple text found in hard-copy books. The DMI has used instructional design principles typically reserved for the classroom to build a powerful learning tool that can be used anywhere with proven effects.[53]

Why Not Make All Digital Textbooks Interactive?

What makes interactive digital texts more powerful than previous technological advances is the ability for interaction, as opposed to simply providing another mode to transmit information. However, the cost of producing an interactive digital text can be significant, so careful consideration should be made before investing in the development of interactive digital text. The following questions should be considered when deciding whether to invest in its development:

- **Does the subject suit itself to interaction?** If one is studying literature, there is no substitute for reading Shakespeare's *Hamlet*. A developer could digitize the book, but it would be challenging to make it interactive in a way that would enhance learning. Investing in the development of an interactive digital text might only be justified if the anticipated improvement in learning is sufficiently significant.
- **Is it scalable?** Developing an interactive textbook is an expensive and labor-intensive project, so there needs to be sufficient customer demand to justify the investment in an interactive digital textbook. A course, such as Urban Geography, may well be suited as an interactive text, but if only twenty cadets take the course each year, the cost to develop the textbook would be prohibitive.
- **How often does the material need to be updated?** One benefit of a digital book is that it can constantly be updated; it is not outdated the day it is printed. A student can purchase the text and receive lifetime updates. However, developers should consider the cost of routine edits from the onset. If the textbook is one that requires significant updates on a frequent basis, then it may be too expensive to produce.
- **Is the material free or copyrighted?** When developing the Military Science interactive text, much of the material comes from military doctrine, which is public domain. By contrast, content for the Military History text cannot be pulled from existing books due to copyright laws, so authors needed to be hired to write content.

Conclusion

Interactive digital textbooks can significantly improve student learning when designed using principles from learning theory; and West Point's investment in these textbooks for its Military Science and Military History courses have and will continue to improve student learning. The current wave of technological advances is especially promising as it ensures the textbook is only one swipe or click away from students at any given time, given that their smartphones or tablets are never far away. But it is not infallible. Caution is in order, since not every subject can benefit from interaction or justify the investment. Nonetheless, interactive digital textbooks hold enormous potential.

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