The Design and Application of the Digital Backpack

James D. Basham and Helen Meyer
University of Cincinnati

Ernest Perry
National Underground Railroad Freedom Center

Abstract

In this study, we introduce the digital backpack as a means for creating a rich learning experience for students of multiple ages. Development, design, and refinement of the digital backpack are grounded in the theoretical framework of Universal Design for Learning using a Design-Based Research (DBR) model. This article presents the design and initial testing of the digital backpack. We discuss the refinement of the digital backpack in a case format that involved three DBR cycles focused on increasingly complex outcomes of design and learning. Finally, the article offers the lessons learned to encourage further exploration of this technology. (Keywords: digital backpack, Universal Design for Learning, design-based research, mobile technology)

There is no single magic technology in education for learning. In fact, deploying a useful technology infrastructure for teaching and learning has proven difficult for many districts and teachers (Barron, Kemker, Harmes, & Kalybjian, 2003; Cuban, Kirkpatrick, & Peck, 2001; Zhao & Frank, 2001; Zhao, Pugh, Sheldon, & Byers, 2002). Rather than focusing the adoption of technology on enhanced student learning, districts often start with budgetary considerations and a "what this will buy us" process for integrating technology. As a result of this directional thinking, districts end up with technology but no strategy for effectively integrating it into instruction and learning (Bauer & Kenton, 2005). We would suggest that, to provide effective technology use, districts have to reverse the direction of their thinking and start thinking backwards.

The focus of backwards design (Wiggins & McTighe, 2005) is on the desired learning outcomes rather than on the type or amount of technology to be made available in the learning environment. Through a backwards design, the designer of the learning experience identifies the planned outcomes of the learning process. These outcomes will include the intended "big ideas" (the overarching concepts and understandings to be had by learners) and measureable results that the learners should walk away from the experience with. Upon deciding on the outcomes, the designer then plans the assessment protocols to measure the results. By design, the measures should include multiple means of assessment, including authentic "real-life"

forms of demonstrating understanding (Wiggins & McTighe, 2005). Finally, the designer plans the instructional experience to provide for the learning. Through the process of using backwards design, a designer might consider various design questions: What are the essential learning outcomes we want for all students? What are the big ideas being taught? How do the new understandings associate with student background knowledge? How are students going to demonstrate these learning outcomes? How are we going to measure success? What are the barriers to achieving these learning outcomes? How do we provide for the desired learning outcomes and overcome these barriers? Thus, by starting backwards, districts and teachers can begin a thoughtful process of instructional design.

In this process of design, districts and teachers quickly realize that many barriers exist within the traditional learning environment. All school districts' populations are diverse, albeit in some cases the diversity is less visibly noticeable. Diversity includes students from various cultures, with varied abilities, disabilities, interests, experiential backgrounds, and even language use. The observable and not so observable diversity of student populations requires curricular and instructional design that is designed for all students.

As this article will discuss in more detail later, Universal Design for Learning (UDL) is a purposeful instructional design framework that offers multiple means for teachers to provide for knowledge representation for students to learn information, for students to demonstrate their understanding, and for students to engage in learning (Center of Applied Special Technology [CAST], 2008; Rose & Meyer, 2002). At the heart of UDL is appropriate technology integration to provide supports for diverse learning needs.

In this article, we define the concept and necessary components of the digital backpack. We discuss its potential as a readily accessible and adaptable means for schools to appropriately provide for desired outcomes in diverse student environments. We exemplify the development and use of digital backpack in a case presentation that followed a DBR model. In the discussion, we focus on how the presented case may inform further design, implementation, and research of the digital backpacks for students in various learning environments.

The Digital Backpack

The initial design consideration for our development was to provide a highly mobile, flexible, efficient, and scalable technology experience for students that could be taken outside of a school's walls. In addition, it needed to provide students with multiple means for representation, expression, and engagement in the learning environment (the three principles of UDL). Various ideas were discussed, but the final concept was the digital backpack.

A digital backpack is mobile technology in a backpack that includes detailed hardware, software, and instructional support materials to provide for project-based learning experiences in various formal and informal

environments. All digital backpacks have three core components, including foundational technology to provide for multiple means of engagement and expression, modular technology to provide for differentiated instruction and learning, curricular or student support (typically these peripherals can be added to or removed from the backpack depending on the current project), and instructional support material presented in multiple formats for the representation of knowledge as well as meeting individual project/lesson needs.

Digital Backpacks in Scholarly Literature

The idea of focusing on the design and implementation of a digital backpack has received little discussion in academic literature. In the earliest located publication, Hoagland, Aplyn, and Rice (2001) equated a digital backpack with a digital portfolio because it presented outcomes and artifacts of student learning. Within this design, the digital backpack was a digital element and lacked physical properties. Hoagland et al. noted the importance of portability and students' ability to express content understanding through the digital elements of the backpack. Although their digital backpack was vastly different from our design, the concept of a portable means for students to express understanding is important to our design.

Moving toward a physical backpack, Wolfson and Amirian (2003) identified a digital backpack as a backpack loaded with the technology associated with professional development. The purpose of their backpack was to provide technology access to professional development participants. Viewing it slightly differently, Henke (2005) depicted the digital backpack as a backpack filled with student-selected tools (e.g., cell phone, digital camera, iPod, calculator). Within the one-page display, Henke indicates that students would select tools in order to better their learning. Henke also depicted a potential learning outcome for incorporating each device. For instance, a student could use an iPod to listen to a podcast on academic content.

In the most comprehensive article on digital backpacks, Amirian (2007) focused on finding a solution to overcome many technology integration issues. Similar to the ideas in Wolfson and Amirian (2003), Amirian (2007) suggested loading a backpack with the technology that university faculty and teachers need access to for their instruction. Beyond equipment access, the concept of the Amirian (2007) digital backpack seemed underdeveloped, especially around the various environmental and learning parameters. There was little explanation of how the technology of the backpack's structure actually integrated into the learning process. Much of the article focused on the professional development experience that incorporated the backpack rather than on the digital backpack structure itself. Although vastly different in goals and design from our digital backpacks, Amirian's design showed that, after this intensive experience, the participants had enthusiastic perceptions of the backpack concept.

Through this comprehensive but brief review of literature, we have concluded that little work has been done on the purposeful design of a digital backpack structure. Henke (2005) focused on an open system in which the students selected technology to support their own learning. Wolfson and Amirian (2003) as well as Amirian (2007) focused on providing access to equipment or technology for professional development and instruction. The focus of our research was to develop a flexible digital backpack structure that could be adapted to various project-based learning experiences in multiple settings with a variety of students.

A major concept that played a role in the design of our digital backpacks was the idea of supporting small groups of students on collaborative projects and problems. The use of the digital backpack with small groups of students fits with the historic notion of Lave and Wagner's (1991) ideas of apprenticeship learning and distributed expertise, and Salomon's (1993) views of distributed cognition and learning with computers. The work in collaborative groups allows students to take on problems or projects that may be too complex for individuals, so that students can gain experience with complex learning and technology tools over time. Therefore, it is imperative that students have multiple experiences and opportunities to work with the digital backpack. As such, we feel school districts can invest a portion of their technology budget to develop school-based sets of digital backpacks that several classes of teachers can share. Beyond providing for multiple means for engagement in learning, this shared design reduces the cost for scalability and works toward 21st-century skills.

Core Components of the Digital Backpack

Foundational technologies. The foundational technologies are the hardware and software systems used as the general building blocks for a lesson or project. These technologies are flexible but generally remain constant within the backpack, regardless of student need or project design. In our digital backpacks, the foundational technologies included a MacBook Pro and standard Macintosh digital media software that comes loaded on the machine. The core software included applications for word processing, movie making, audio editing, listening to audio, and Web access. Foundational technology should be small enough to fit in a backpack and provide a work base for the modular technologies. A consistent record of stable functionality in various environments without constant need for ongoing support is a final and important consideration.

Modular technologies. These consist of hardware and software systems that are provided to achieve specific curricular, instructional, and/or student learning needs and outcomes. In our initial digital backpack design, these technologies included a hard-drive-based camcorder, a still camera, an iPod with an external microphone attachment, and a tripod. Other

examples of digital backpack modular technologies include portable USB digital microscopes, scientific probes, wireless sensors, and infrared-based thermometers. The modular technologies are proactively integrated into a digital backpack to build on to the foundational technology and to focus specifically on the needs of the students and the curricular-based project. Modular technologies not needed for a specified learning experience can easily be removed from the backpack and stored safely, although the software to support these modular technologies should be left on the computer.

Instructional support materials. Instruction and learning materials are essential components of the digital backpack. Instructional support materials include any material (digital or otherwise) that provides structure and/or support for the learning experience. In the case discussed in the next section, the instructional support materials included in the initial backpack explained the learning goals, objectives, and big ideas of the project to the students. Further support material established student roles, digital and paper-based design templates for storyboarding movies, background instructional content (in digital text, printed text, audio, and video formats) on the various museum exhibits the project would use, a project timeline, project design parameters, and a plan of action. It takes time to develop, locate, and proactively provide instructional support materials. These materials should support multiple means of knowledge representation, specific student need, the lesson, and any associated project. Many of these supports already exist (e.g., iTunes U, Discovery Education), whereas others must to be created. The instructional support materials should be revised or modified based on the desired outcomes and student need.

Digital Backpacks and Universal Design for Learning

We designed our digital backpacks with the tenets of UDL in mind. The modular and instructional material components highlight the features of the digital backpack that meet the requirements for UDL. Scientifically based frameworks, such as UDL, can provide meaningful student-centered relationships among curriculum, instruction, and assessment. The UDL framework shifts the focus away from "technology" as something that's simply technological to provide a more purposeful, well-designed, evidence-based, and accessible learning environment that meets the needs of our diverse student population. Based on neurological and cognitive research, UDL moves the focus from a one-size-fits-all structure to a framework that provides for multiple means of representation, expression, and engagement (CAST, 2008; Rose & Meyer, 2002). Moreover, when done effectively, UDL provides a student-centered environment that integrates modern technology to meet desired outcomes through various pedagogical, curricular, and instructional approaches.

Within recent legislation, UDL was defined by the Higher Education Opportunity Act of 2008 (HEOA) and has been advocated in the reauthorization

of the Elementary and Secondary Education Act, commonly known as No Child Left Behind (NCLB)(NASDE, 2009). According to the HEOA:

> The term "universal design for learning" means a scientifically valid framework for guiding educational practice that—(A) provides flexibility in the ways information is presented, in the ways students respond or demonstrate knowledge and skills, and in the ways students are engaged; and (B) reduces barriers in instruction, provides appropriate accommodations, supports, and challenges, and maintains high achievement expectations for all students, including students with disabilities and students who are limited English proficient.

Overall, the UDL framework provides multiple solutions that support student learning. The key to UDL is to proactively design for diverse students needs (CAST, 2008). By design, this framework also encourages a focus on flexibility to provide for known as well as unknown student, curricular, or instructional variables. This flexibility avoids the need for future large-scale retrofitting of learning environments. In the end, purposeful, proactive, and student-centered designed learning environments provide better outcomes for all students.

Design-Based Research and Optimizing the Digital Backpack

As previously noted, the digital backpack was developed to provide a mobile, flexible, efficient, and scalable design that supports a variety of learners and learning experiences. Since the development of the first digital backpack, the same design framework has been used in a variety of formal and informal learning environments, including classrooms, zoos, museums, and community experiences. The following case illustrates the development and use of the first digital backpack.

The Case Context

We executed the design and application of this digital backpack experience with monetary support from the KnowledgeWorks Foundation. Apple Inc. also provided in-kind support (e.g., personnel time, training). We established a collaborative design team comprised of personnel from the National Underground Railroad Freedom Center (Freedom Center), Apple Inc., and the University of Cincinnati with these supports. The team set out to design and assess a modern learning experience that engaged diverse groups of students around an enduring social and political question: "What is freedom?" Importantly, the team did not want to simply create a technology experience. We were motivated to develop a project that could provide a range of learners (grades 6 through college) with an experience that occurred outside of conventional classroom settings and focused on historical and contemporary issues of culture and freedom. Therefore, learning outcomes explicitly involved both subject-area content and technology.

Located on the banks of the Ohio River in Cincinnati, Ohio, the Freedom Center was the site for the development and application of the first digital backpack. The Freedom Center's mission is to "reveal the stories about freedom's heroes, from the era of the Underground Railroad to contemporary times, challenging and inspiring everyone to take courageous steps for freedom today" (National Underground Railroad Freedom Center, 2009). It carries out this mission through a variety of educational experiences, including its digital learning environment that enables learners to access its major exhibits, scholarship, and other programming using media-rich experiences onsite and online.

The physical and digital operations of the Freedom Center played an important backdrop for the design of the Digital backpack. First, the physical structure provided a proving ground for engaging learners in an open learning environment. As a museum, the Freedom Center environment is filled with various exhibits, objects, and artifacts to engage learners, as well as a number of potential distractions (e.g., other patrons, a café). Second, the Freedom Center had a variety of digital assets (e.g., movies, podcasts) that could be easily incorporated into the digital backpack design structure. These ready-made materials helped us quickly develop various backpack structures and decrease design costs. Finally, from a conceptual stance, the inherent relationship between learning and freedom was forever present in the design process. Very early on, the team knew we had to design the digital backpack to overcome various barriers to learning.

The UDL framework provided the primary vehicle for overcoming learning and accessibility barriers, but the digital backpack also needed to meet student and site-based parameters. For instance, we addressed many of the concerns of technology use in schools for student learning. We understood that variables such as "on demand" technology access (Bauer & Kenton, 2005; Cuban et al., 2001, Dexter & Riedel, 2003; Pasternak, 2007), support (Bauer & Kenton, 2005; Cuban, 2001; Cuban et al., 2001; Dexter & Riedel, 2003), teacher training (Forgasz, 2006; Hew & Brush, 2006), and pedagogical and curricular alignment (Cuban et al., 2001; Garcia & Rose, 2007; Levin & Wadmany, 2008) all play roles that diminish the value of technology for learning in too many school settings. From the student learning side, we understood there would be concerns with technology and task alignment (Goodhue & Thompson, 1995), length of time it takes to implement (Bauer & Kenton, 2005), the general usefulness in the learning process (Hornik, Johnson, & Wu, 2007; Johnson & Maddux, 2007), and student skill/training level (Bauer & Kenton, 2005). Additionally, the Freedom Center, like any other field site, presented parameters that had to be accounted for in our design. These included being able to engage students in a meaningful learning experience in a single short period (generally three to four hours), having students work collaboratively in large open spaces with varying degrees of adult supervision, and using a public space with any number of outside patrons present.

Researching the Digital Backpack for Formative Evidence

The team was aware that there was a need to gather initial data on the usefulness of the digital backpack as a technology and learning experience for students. To gain a more complete understanding of the digital backpack experience, we viewed it as an "applied design." Design-based research (DBR) provides usable research in authentic educational environments (The Design Based-Research Collective, 2003) to understand and refine new learning technologies. The National Science Foundation identified DBR as a critical research practice for rapidly prototyping and testing educational innovations (see Borgman et al., 2008). DBR encourages the interlinking of theory of instruction and learning with a host of methods to provide formative research (Collins, Joseph, & Bielaczyc, 2004). Essentially, DBR uses cycles of design, including data collection, analysis, and redesign. Dede (2004) promotes a DBR model that is tightly aligned with a theoretical foundation, has a controlled data-collection and analysis model, and uses predetermined points of success to define a stopping point for DBR.

Following the DBR protocol, we established a theoretical foundation, developed tightly controlled data-collection and analysis systems, and defined measureable performance outcomes for stop points. Student teams produce a five- to six-minute digital movie on the theme of freedom. This design led to three DBR cycles. Throughout the three cycles of DBR, the team focused on the following questions:

- What equipment, environmental, and instructional factors contributed to the outcome of the design cycle?
- Should the factors be modified to obtain the desired outcome, and if so, how?

Participants

Participants for Cycle 1 included seven upper-level high school students from a rural school district with a stated focus on technology. The three male and four female students had all been previously enrolled in a technology and media course at the school and had made digital movies with various editing tools, including the one used in the backpack. All students were familiar with preproduction, production, and postproduction media development process as well as the hardware and software. The media teacher and an administrator attended the trip to the Freedom Center when the students worked with the digital backpack. None of the participants in Cycle 1 had visited the Freedom Center.

Participants in Cycles 2 and 3 were from the same urban high school. Each of the students had the same social studies teacher and was receiving a "C" or higher in social studies. The social studies teacher also attended the digital backpack experiences. The Cycle 2 participants included 14 students in 11th grade; all were African-American and included six males and eight

females. The students had previous experience with the process of moviemaking, hardware, and software (although an earlier version of movie editing software, iMovie) and were familiar with storyboarding and other preproduction activities. Cycle 3 involved 14 ninth grade students. Thirteen of the students were African-American and one was white; ten were female and four were male; and one student had an identified learning disability. These students had no school-based experience with digital moviemaking, hardware, or software.

Data

Data gathering across the three cycles was consistent in many areas, but we modified the process to better understand the design needs in the later cycles. In all cycles, we gathered data through participant observations, video-recorded observations, field notes, and student-generated artifacts. In Cycles 2 and 3, we collected additional data through student surveys, student interviews, and more tightly structured process artifacts. We used the surveys to gather students' initial understanding of freedom and past technology experiences (both in and out of school). The technology survey was based on an instrument used in Ching, Basham, and Jang (2005). We asked observers to focus on the students' use of the technology, including what technology they used, when and how often they used items, and the ease with which they used different technologies. The student interviews asked students about affective aspects of the experience as well as their perceived learning about both freedom and using the digital backpack technologies.

The Workings of the Three Cycles

To complete the desired outcome, evidence-design-based changes were made across the three DBR cycles. Each group was charged with developing media production on "What is Freedom?" in a four- to five-hour time period. The general process for each cycle included an introduction to the project, a review of the backpack contents with a quick overview of hardware operations (about 15 minutes), preproduction/concept development, time on the museum exhibit floor (production), and media postproduction.

DBR Cycle 1. All students in Cycle 1 were on the same development team and used one backpack. This group had full access to the museum. The students in this cycle spent roughly one and a half hours of preproduction prior to arrival at the Freedom Center. Once on site, an educational docent gave them an hour-long tour of the exhibits, and they then had nearly two hours of production time through the exhibit areas. The cycle concluded with a two-hour postproduction period. Some students in this group brought equipment of their own and independently gathered media to integrate into the project. The students were unable to complete a cohesive media production around a single theme.

DBR Cycle 2. Participants in Cycle 2 had a single 45-minute afterschool briefing about the project. This briefing included an introduction to the overall concept of the project in addition to transportation details on the city bus to the Freedom Center. The students were placed in work teams for the task and were asked to select roles (e.g., camera person, director, on-screen personality, sound specialist). Students completed a worksheet that asked them to respond to the question "What freedom means to me?" and took the presurvey.

On the day of the Freedom Center visit, the students started in a meeting room and were given time to explore the digital backpack equipment. Each digital backpack had instructional support materials for one designated exhibit loaded onto the MacBook Pro. After this introduction, the groups had an hour of preproduction, which included eating lunch.

Once the students moved to the exhibit floor, they were in production, collecting media, for one and a half hours. Forty minutes into the production time, the groups moved to other places on the exhibit floor. They continued to capture video and audio media as they moved to other exhibits. The students had approximately one hour for postproduction activities. As needed, the students were provided with small group support in postproduction.

DBR Cycle 3. The ninth grade students attended the same school-based meeting that the 11th graders did in Cycle 2. Their visit to the Freedom Center occurred two days after the preparation meeting. The structure of the Cycle 3 visit was similar to Cycle 2, with the following exceptions: The ninth grade students were given 15 minutes to receive instruction and practice using the equipment, were required to complete their storyboards before leaving the preproduction room, and had only 45 minutes with the exhibits. Also, at the start of the postproduction, they received a 15-minute instructional session on downloading the captured media and using iMovie '08.

Data Analysis

Using suggestions from Miles and Huberman (1994) and Bogdan and Biklen (1998), a first level of analysis was conducted immediately following each cycle. Importantly, the researchers debriefed with museum personnel and the teachers within 24 hours of a cycle to reflect on the outcomes and make decisions for next steps. After each cycle, initial analysis of data involved comparing artifacts, field notes, and observer reflections to develop a working theory to further understand the data and design revisions. The starting point for data review in each cycle addressed project completion, media gathered, and bottlenecks. We reviewed the student-created digital artifacts to identify and compare totality of the media gathered with the actual media used and the media left unprocessed at the end of the day. This comparison of project completion and media quantities provided an analytical lens through which to view field notes of the students engaged in the process.

We were able to identify places where the equipment was insufficient for the students' demands, where they needed more or less time, and where they needed more support.

The second level of analysis focused on nondigital artifacts generated by the students and student interviews. The artifacts included the project handouts and pre- and postsurveys from the participants in Cycles 2 and 3. We analyzed these items to understand the student learning process in regard to the use of the technology and the concept of freedom. We used simple frequency counts with the technology-use surveys to understand the student groups' level of experience and knowledge with the specific technologies used in the digital backpack. We analyzed the nondigital artifacts to trace how students initially described freedom as individuals, how this was processed into a group document in the form of a storyboard, and how it was finally reflected in the final products. In the interviews, we directly asked the students how they used the different technologies, if they felt the technology enhanced or interfered with learning about freedom, and what changes they would recommend. Tracking the concept of freedom led to working theories focused on the clarity of the instructional support materials and the amount of guidance students needed to effectively use the support materials.

The final level of analysis occurred after all the cycles were complete. In this case, we used the video observations to address the same areas as above. This video analysis confirmed the findings and provided details about outcomes that were not recorded in field notes. The video analysis was most helpful in understanding media used and who used the media.

Results

The results for each design cycle are reported separately, even though the entirety of the process is needed to fully understand DBR and the use of the digital backpacks. In sharing the results, we have highlighted the natural process of DBR that leads to the effective refinement of a UDL learning experience.

Design Cycle 1: Proof-of-Concept Equipment Demands and Needs

As is common in an initial testing of a concept, the first design cycle is the most open. The major focus of this cycle was to demonstrate proof of concept. It essentially determined if the concept would be worth further development; therefore, data gathering focused on large-scale issues, and other factors were left unattended. As such, all the preproduction work took place at the school, was managed by the media-teacher, and was completed without much instructional support material. During production, students were observed discussing technology issues and design components rather than content. When the students did focus on content, it could be described as just-in-time learning, such as reading exhibit text or asking museum personnel for an overview of an exhibit. The students ran from exhibit to

exhibit (sometimes literally), to capture as much as possible on video, with little focus on what the video represented, why they might want that video segment, or how it fit their concept of freedom. For instance, the student group embedded only a few specific historical reference points (e.g., names of slaves, slave traders, or trade routes) in media that were available from the exhibit text or information the docent provided during the tour.

Also during this production, one student took it upon herself to start up the postproduction by importing digital content. She set up the laptop and sat on the floor while other students brought over the modular devices to import media. During the production phase, the students imported all digital material except the video. After importing their own content, a few students used the wireless network to gather materials (images, sounds, movies) from sources outside the Freedom Center.

During postproduction importing, the video footage became a task-ending bottleneck. Once the MiniDV camcorder was set up to import, the students were left with time to sit around waiting for the footage to download. Finally, the students were instructed to stop the import and work with whatever footage was imported. The observers noted that many of the students had to return to preproduction tasks to determine what they wanted their movies to say. Ultimately, the students in Cycle 1 never completed the desired task in the designated time period.

Implications of Cycle 1

Many lessons were learned from the results of Cycle 1; however, the team determined that two distinct items needed to be addressed to provide better outcomes. It was evident to the team that equipment caused bottlenecks (especially with MiniDV camcorders) that left too many students with nothing to do and placed undue emphasis on dealing with the technology versus dealing with the content. So the first suggested change involved major equipment changes, including faster laptops and camcorders with hard drives. Between Cycles 1 and 2, Apple also released a new version of the movie editing system (iMovie). Additionally, we made various minor equipment changes for convenience. For instance, on the backpack itself we added a means to attach a tripod for carrying ease.

The second major refinement involved creating a project structure that required each student to take the lead on some aspect of the project and ensure that each modular technology fit into the structure of the task. To accomplish this, the team developed instructional support materials that clearly delineated the task to be accomplished as well as a working framework to allow this to happen. During preproduction, each student was assigned a group role (e.g., videographer, photographer, editor, sound person, on-screen personality) that engaged that student with a specific technology.

These two major refinements were intended to improve the working experience with the technology and provide a reason to include all technologies,

rather than relying too heavily on video footage. As a byproduct of changing the technology demands of the project, we were also able to increase all students' engagement in the project, as each had a specified role, and we implicitly enhanced the need for preproduction work around which technology would best represent the content.

Design Cycle 2: The Demands of the Learning Environment

Video observations of preproduction for Cycle 2 showed that the students did not progress in a linear or shared fashion. Although each student had an assigned technology role, during planning the student groups jumped between activities, as each group member wanted to prioritize based on his or her role. Therefore, within a group, one or two students would be working the equipment while one to two others brainstormed ideas, but the group devoted little collaborative effort to developing its storyboard. When a group did work on the storyboard, students all threw in ideas that they thought were relevant, but there was little process for eliminating ideas or coming to consensus. None of the three teams completed their storyboards.

We made important observations during the Cycle 2 production period that supported the changes made between Cycles 1 and 2. During production, teams spent considerable time gathering footage about their assigned exhibits. All teams used each of the technologies in the backpack, each student was engaged with his or her assigned task within the group, and the groups stayed together while they gathered data on their exhibit. We noticed that the students tended to remain in their self-assigned roles (e.g., director/producer, camera person, on-screen personality) regardless of whether someone was having difficulty completing the needed tasks.

We observed the students in Cycle 2 discussing deeper content-related themes. Different groups discussed and included specific instances related to the denial of freedom in global contexts, such as the Holocaust and the war in Rwanda. This showed that they connected the social studies content they learned in school with the museum exhibits. They also included specific references to slavery, the slave trade, and human oppression in the United States and other countries that were not part explicitly part of the school curriculum but were part of the materials presented in the self-study instructional materials found in the backpacks.

Finally, the Cycle 2 students purposefully engaged other museum patrons. Team members asked museum patrons for interviews and recorded, either on video or using the digital audio, the patrons' views of freedom and their thoughts toward the exhibit or the freedom center. Each of the three groups in Cycle 2 completed gathering their material in an hour or less. Once the teams were done with their assigned exhibits, they began to gather media footage on other exhibits for the remaining half-hour.

During postproduction, the changes in technology significantly reduced the import bottleneck; each team still had a few minutes of processing time.

However, due to the students' lack of initial consensus on the themes of the movies, even with reduced processing time, they did not complete the final task. The students obtained interesting and powerful footage during production time, but it was more than they could incorporate and edit into a movie, especially given the one-hour allotted time for postproduction.

Additionally, the students struggled with the graphical user interface (GUI) changes in the movie editing software. All of the 11th grade students had worked with the previous version of the editing software. The student groups would discuss how they wanted to do something (e. g., a transition) but could not easily figure out how to complete the task in the newer software. After initial attempts, a group would give up or ask for help and have to wait for a support member to answer questions about interface or application changes.

Implications of Cycle 2

The primary design changes from the results of Cycle 2 involved procedural refinement to alleviate constraints in the learning environment. In both Cycles 1 and 2, time was a major constraint. School visits to museums are always constrained by time, and to leave the learning task unfinished diminishes the learning value substantially. The changes made between Cycles 1 and 2 demonstrated potential for enhanced learning, but if the final product cannot be achieved in the instructional timeframe or set learning environment, then the design cannot be considered successful. The simple, nontechnological refinements of the digital backpack between Cycles 2 and 3 addressed issues relating to creating an effective learning environment. The overriding change was to provide the student groups with a work timeline.

Beyond the general work timeline, our first objective was to make the preproduction a more effective learning experience. Within preproduction, we determined that students must complete their storyboards onsite but prior to production. Moreover, each group must have consensus about what is being included. We also wanted each student to have some familiarity with all of the technologies, no matter what their selected role was, so we included a brief introduction to each of the modular technologies and some small amount of hands-on practice time.

As in Cycle 1, in Cycle 2 we determined that too much time was spent on the museum floor during production. Based on this observation, in Cycle 3 we decreased the time on the exhibit floor to 45 minutes total and encouraged the students to work from their storyboards and work timelines. Finally, we sought to reduce the inefficiency of the postproduction period. We developed a 15-minute micro-lesson on the use of iMovie that incorporated finding the program tutorials so that the student groups would do more self-directed learning rather than waiting for team members to answer questions.

Design Cycle 3: Achieving Student Learning

The new time and task-oriented support provided by the development team allowed the students to focus their preproduction work and progress in a more linear manner, as compared to Cycle 2. The student groups generally followed the established timeline of tasks. All students practiced with each of the modular pieces of equipment, and all teams in Cycle 3 completed their storyboards in the allotted time.

During production, the limited time on the floor allowed students to accomplish the task and reduced the amount of captured media to be processed in postproduction. The student groups were more strategic with the media they captured, generally capturing media based on the preproduction plans. The students in each group tended to serve in their primary roles, but each student tried at least one other role. As in Cycle 2, the students in Cycle 3 all independently incorporated views from other patrons by interviewing them on video or through audio footage. All the student groups in Cycle 3 used each of the modular technologies during their production time; however, they used the digital video to a much greater extent than the students in previous cycles.

Similar to their older peers in Cycle 2, the students in Cycle 3 drew on and connected their ideas with previous instruction and knowledge from the school curriculum. The ninth graders focused more on national themes of freedom rather than on the global themes that Cycle 2 students focused on, but in both cycles the students actively connected what they learned in their school setting with the museum experience. They included themes such as ending slavery and segregation, relations between cultures and races, and the ongoing struggle for freedom in the United States.

During postproduction, the micro-lesson (defined as ≤ 15 minutes) on iMovie '08 was the students' first introduction to video editing. The 15 minutes of instruction provided an overview and pointed them to online instructional tutorials in the application. A minimal amount of time was lost for uploading the video, as the groups had very little extra footage. Once the digital footage was uploaded, the students used their storyboards to organize major segments of the video. The student groups did encounter editing problems, but rather than stop and wait for help, the students in Cycle 3 clicked around in the software looking for their own answers. The micro-lesson, combined with online tutorials and support to individual groups, helped each group complete the assigned project.

Interestingly, of the three groups, the ninth grade students, who had the least amount of experience using the technology, were the only ones who completed their movies. Results of the presurvey measuring technology use indicated the students in Cycles 2 and 3 had significantly different technology experiences (t 2.281, MD .733, $p < .05$ two-tailed). With lower mean scores aligning with more experience, the 11th grade group had more technology experiences (Mean 3.15, SD .67832) when compared to the 9th grade students (Mean 3.88, SD .94012).

Discussion

Early evidence supports the digital backpack as a simple solution for integrating technology into curriculum. As such, the digital backpack provides a structure for districts and teachers to proactively plan how to they can support diverse learners in a project-based learning environment. Each of the three components (foundational technologies, modular technologies, and instructional support materials) of the digital backpack were needed to overcome the various constraints and provided a successful platform facilitating a modern learning experience. The design of the digital backpack, including the instructional planning components, allowed students to complete off-site but technology-rich learning in a short period of time. The use of the digital backpack encouraged students to take ownership of what and why they were learning, provided a platform for creating an authentic integrated curricular experience, and mediated the range of technology experiences found in many classrooms.

Ironically, the students with the least amount of technology experience were able to complete the project in the most efficient fashion. This finding has been discussed many times by the design team. It can be concluded that many variables likely played a role in this finding. A couple of variables that likely contributed to this finding were the GUI changes to the movie editing software and the greater focus on scaffolding within the instructional design process. Either through the scaffolded design or through internalized understanding, these students also did a better job self-regulating, strategically planning, and focusing on their vision. As noted in the findings, these groups collected footage that aligned directly with their storyboards, and very little footage went to waste. The success of the initial digital backpack, as well as other designs, has shown that a strong focus on a scaffolded instructional design is important to engaging all learners. Although more research is needed, there is some initial evidence that, regardless of technology background, students can achieve the intended learning outcomes when they have appropriate supports, structure, and focus.

Using the UDL Framework

From a UDL perspective, the digital backpack provided multiple means of representation, expression, and engagement. The students were able to gain a new understanding of freedom through the various forms of representation in the instructional support materials. Background materials for the second and third cycles were available in digital and print formats, and information about the exhibits were presented through podcasts, videos, and digital documents. Moreover, the design of the instructional materials (including conversations with the design team) cultivated students' prior understanding by identifying connections between the old (school-based curriculum) and new content. The backpack project provided for multiple means of expression through the collaborative design and development of a movie. Students

determined what their own products would include and how they would demonstrate their understanding of the content. Each group of students established and managed its own goals, met structured checkpoints, and developed a connected level of understanding of the content, as evident in the final products and through conversations. Related to engagement, students chose their own roles, focused their time within a scaffolded structure, and self-regulated their level of challenge and support. The alignment of the digital backpack with the UDL framework provided a flexible and scalable learning experience that allowed each student to succeed in learning content and using new technologies.

Future Practice: Scaling Up the Digital Backpack

The three core components (foundational technology, modular technology, and instructional support materials) of the digital backpacks provide an approachable process for designing various integrated learning experiences for teachers. Generally, the foundational technologies provide the building blocks, whereas the instructional supports and modular technology may change based on the design of the lesson or the needs of the students. For instance, various configurations of digital backpacks are being used through a number science, technology, engineering, and math (STEM) FUSION Center school-based initiatives at the University of Cincinnati. Some of these backpacks are configured for media development projects (similar to the Freedom Center backpack), whereas others focus on data collection and analysis. The data-collection digital backpacks contain various modular technologies, such as USB microscopes, and various USB/wireless sensors, such as temperature sensors and magnetic field sensors, which are all paired with data-analysis software (e.g., InspireData). Notably, most digital backpacks contain either a camera or digital camcorder to help students record and recall their field experiences.

Designing other digital backpacks requires an initial focus on the desired outcomes, instructional needs (including potential barriers), and project-based learning experience under the UDL framework. Under this prospective, a project-based learning experience includes students' completion of a "project" through the construction or engineering of a product (e. g., 3D object, movie, paper, presentation file, podcasts, website). Importantly, attention should be focused on the UDL notion of proactively designing for multiple means of representation, expression, and engagement. Moreover, this research indicated that preparation must also focus on structuring the digital backpack experience to provide for desired student engagement and a semi-structured project workflow. Later backpack experiences have also shown that proactively facilitating students' design of their own workflow has been successful in achieving the desired outcomes.

Importantly, cost should not be the initial consideration of designing a digital backpack. Recently, a FUSION STEM school outfitted its entire building

with an array of learner- and curriculum-focused digital backpack designs for less than $12,000. As previously discussed, the digital backpack has a flexible design that can use the same foundational technology to support various diverse student groups across multiple content areas. Moreover, the design can readily incorporate modular and instructional technology that is either free or widely available, such as podcasts on iTunes U, Google Docs, moviemaking software, and inexpensive video cameras. The UDL design should incite planning among curriculum, special education, and technology personnel if it is not already taking place. Collaborative planning, focused on supporting all students, often opens opportunities for developing greater understanding of district needs as well as pooling resources to meet those needs.

Future Research: Cognition and Learning

Through a DBR model, the initial proof of concept, prototyping, and field study have indicated that the digital backpack might provide a simple solution for engaging students in a modern learning process. More research is needed on how effective the digital backpack is in supporting new content-based learning as well as in reinforcing connections with background knowledge. This could be especially important in content that is often difficult for students, such as science and math. Future research should also focus on the efficacy of the digital backpack and other UDL-based instructional designs for supporting diverse instructional and student needs. For instance, this research supported the idea that particular attention should be paid to the scaffolded design process for engaging learners. What other design parameters and thresholds exist within the digital backpack design, across the UDL framework, and with the use of modern technology in learning? Future research could suggest various instructional design structures and solutions to support the diversity within our student population, including students with disabilities and those who are limited English proficient.

Along with supporting student learning, we are interested in how districts and teachers adopt and interpret the use of the digital backpack. Generally, how does a mobile and flexible design such as the digital backpack support greater understanding with districts and teachers in areas of instructional design, technology use, and overcoming the barriers to learning? Additionally, if districts focus on a backwards design process and a scientifically valid design framework to support all learners, such as UDL, what relationships emerge among their curriculum, special education, and technology personnel? Based on the same understanding, what flexible, efficient, and scalable technologies do districts target to meet diverse student instructional needs? How do teachers adopt and customize digital backpacks to support their content and student population? In this same vein, we are keenly interested in investigating how effectively digital backpacks can be scaled up and packaged to support various 21st-century standards-based learning environments.

Conclusion

In this article, we provided an initial design and structure for supporting the development of an instructional technology solution dubbed the digital backpack. Based on the notions of backwards design and the UDL framework, the simplistic and tangible design components of the backpack included foundational technology, modular technology, and instructional technology supports. We believe this simple design structure provides a targeted yet flexible and scalable solution for districts and individual teachers to thoughtfully enhance instruction in various learning environments.

Author Notes

James D. Basham, PhD, is an assistant professor at the University of Cincinnati in Teacher Education. He is assigned to the UC|FUSION Science, Technology, Engineering, Mathematics, and Medicine (STEMM) research center with teaching appointments in the Special Education and the Instructional Design and Technology programs. He earned his doctorate at the University of Illinois Urbana—Champaign. His research focuses on student learning and behavior in modern learning environments. He has served as a consultant for school districts, universities, state education agencies, and corporate entities on modern learning environments and the integration of Universal Design for Learning (UDL) in classrooms and systems. Correspondence regarding this article should be addressed to James Basham, School of Education, University of Cincinnati, PO BOX 0022, Cincinnati OH 45221-0022. E-mail: james.basham@uc.edu

Helen Meyer, PhD, is an associate professor and chair of the Curriculum and Instruction Program at the University of Cincinnati. She works with UC|FUSION as a science educator. She earned her degree from the University of Wisconsin—Madison with an emphasis on educational reform and development as it relates to science education. She has conducted research and taught courses following a "learning by design" framework to allow for student control of learning. Correspondence regarding this article should be addressed to Helen Meyer, School of Education, University of Cincinnati, PO BOX 0022, Cincinnati OH 45221-0022. E-mail: helen.meyer@uc.edu

Ernest Perry Jr., MA, MAT, is chief innovation officer at the National Underground Railroad Freedom Center. He developed and heads the Freedom Center's Digital Learning Environment, which includes the Digital Backpack Classroom experience and the Underground Railroad Freedom Center Digital Media educational media brand. He earned graduate degrees from Miami University and the Ohio State University. His work and research focuses on the function of public venues as centers of learning innovation, as well as on facilitators of public technology access in urban centers. Correspondence regarding this article should be addressed to Ernest Perry, 50 East Freedom Way, Cincinnati, Ohio 45202. E-mail: eperry@nurfc.org

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