

Student Engagement Capabilities in Mobile GIS:
A Framework for Mobile GIS Education

by

Brandon L. Brooks

A Thesis Presented to the
Faculty of the USC Graduate School
University of Southern California
In Partial Fulfillment of the
Requirements for the Degree
Master of Science
(Geographic Information Science and Technology)

August 2018

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To Rebecca, for the continual encouragement and support.

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Acknowledgments

I am grateful to Professor Karen Kemp, for helping to properly scope and guide this project proposal. I am also thankful to Trevor Denson for his wise advice and moral support throughout this project. I also want to thank Chris LeSueur and the AppStudio for ArcGIS team for their support and guidance. Above all, my thesis advisor, Professor John Wilson, has provided critical support and patience through this process.

List of Abbreviations

| | |
|-------|---|
| AAG | American Association of Geographers |
| API | Application programming interface |
| BoK | Body of knowledge |
| DB | Database |
| GIS | Geographic information system |
| GISci | Geographic information science |
| GIS&T | Geographic information science and technology |
| GTCM | Geospatial Technology Competency Model |
| GUI | Graphical user interface |
| IDE | Integrated development environment |
| JSON | JavaScript object notation |
| NCGIA | National Center for Geographic Information and Analysis |
| NRC | National Research Council |
| QML | Qt modeling language |
| SSI | Spatial Sciences Institute |
| UCGIS | University Consortium of Geographic Information Science |
| USC | University of Southern California |
| WFS | Web feature service |
| WMS | Web map service |

Abstract

Education and GIS have both moved onto mobile platforms to take advantage of the flexibility of having a device wherever the learner or user is. This project brings these innovations onto mobile platforms together with the creation of a mobile framework for GIS education. The framework demonstrates the ability to incorporate a wide variety of GIS as possible components within an educational lesson on GIS&T principles and workflows. This project looks at the research behind GIS&T pedagogy, M-learning with GIS&T, and GIS&T as a tool to enable study. The design and considerations for the project are explained and the authoring and lesson delivery applications built for this project are described. The project's authoring application and its companion lesson delivery application provide a proof-of-concept for GIS learning on the go. The results show that some objectives within the GIS&T Body of Knowledge are well suited for this framework, while some objectives cannot be met using this framework alone. Additional opportunities for development of the framework and research with the existing framework are also presented.

Chapter 1 Introduction

Modern research in adult education shows that both mobile and microlearning are effective methods to enhance informal learning in the workplace (Jomah et al. 2016; Udell and Woodill 2014). These techniques have been shown to be effective components of informal learning, which has been shown in turn to be the most effective and most common form of learning in the workplace (Khaddage, Müller, and Flintoff 2016). There is an expectation within the GIS industry that geospatial knowledge and skills will be critical to more and more workers within the workplace. GIS education, and specifically, adult education will play a key role in this growth of the industry. There is a need for mobile and microlearning within GIS adult education. This project demonstrates an application that allows for the development of micro-packets of content delivered on a mobile platform.

1.1. Motivation

Mobile learning is more than just e-learning in a different format (Casuto 2016). Mobile learning, or m-learning, is already making real contributions to learning methodologies and it is expected to grow quickly in the next few years (Quinn 2011). M-learning, as defined by the e-Learning Guild, emphasizes the importance of using a compact portable device in nearly any location (Martin, Pastore, and Snider 2012). Taking advantage of m-learning capabilities in GIS&T education is a natural fit, considering location is a regular topic in spatial thinking and GIS&T curricula (Unwin 2012).

Microlearning is designed to deliver educational content in concentrated bursts. This shortened time span to learn a concept or principle allows the learner to be engaged with the content whenever they want without the time commitment of larger e-learning courses (Jomah et

al. 2016, 103-110). By combining mobile learning with microlearning, the learner consumes the content where and when they want.

This approach for mobile content in a micro-learning format is common. Lynda.com utilizes this approach with an emphasis on short video lectures. Other platforms for software coding use this approach as well. Some examples include w3schools.org, codecademy.com, and sololearn.com. However, this approach is not common in GIS&T adult training. This project followed the mobile microlearning approach in creating adult learning material that can be consumed anywhere and anytime.

Many of the educational software coding platforms also include coding sandboxes, where learners can interact with the code from the lesson to make the content more engaging and to help it stick, by applying the concepts directly in the code. This project incorporates this concept where the sandbox is a map with which learners can interact. The map displays the principles of the content while also adding location-based services to make the content localized to the learner.

1.2. Project Scope

Four primary components make up the project. In the back end is a shell or framework, that is a mobile GIS engine. This engine takes a template file created by a content author in an authoring application and builds an educational GIS lesson from it. The second component is an authoring application that allows a content author with no programming skills to build a lesson that the GIS engine interprets. The template file, created by the authoring application, is the third component of this project. The fourth component is the delivery application GUI, where learners select the lessons to learn and interact with the Mobile GIS tasks presented in the lesson.

The intended users of this application are adult learners who want to learn about GIS&T concepts and skills. These users can be new to GIS&T, or those who want to use the application to enhance existing skills. The users will see a list of lessons within the application. Each lesson includes conceptual content including graphics, followed by an interactive map, which has geoprocessing tasks enabled to allow the user to see the lesson topic in action. Short knowledge checks are also included to ensure concept comprehension.

1.2.1. The Mobile GIS Engine

The engine incorporates a wide range of mobile GIS functions and tasks. These functions and tasks are created by the authors to incorporate into their lessons. The GIS engine interprets the template file created in the authoring application to fill in the GUI with information from the template file. The engine can also turn on GIS functionality as needed in the interactive map. This functionality includes geoprocessing tools, referencing services, toggling basemaps, and other GIS functionality.

1.2.2. The Authoring Application

The GIS mobile education framework demonstrated here would be harder to populate with lessons if anyone wanting to write a lesson needed an extensive programming background. Therefore an authoring application was developed to dynamically build the template file and make the process of writing lessons easier.

1.2.3. The Template

The template file is a robust file that uses JavaScript Object Notation (JSON) to encode many components available in the GIS engine. The template file is an extensive and dynamic list of fields the author fills out using the authoring application. The mobile GIS engine then

interprets these fields to determine what text, images, web maps, layers, services, and geoprocessing tasks to show within the GUI.

1.2.4. The Application GUI

The GUI includes selection and lesson GUIs. The selection GUI is a gallery that shows all lessons within the application. The lesson GUI consists of schema files that pull content for each section from the template file. Using a schema for the lesson GUI allows all lessons to look and function similarly and provides a seamless experience for the users regardless of who authored the content.

1.3. Thesis Organization

This thesis describes the processes and decisions made in the development of the mobile training application. Chapter 2 provides a literature review of GIS&T pedagogy, mobile learning for GIS&T, and GIS&T as a tool to enable learning. Chapter 3 describes the design of the application including user and functional requirements. This chapter also discusses the choices for software tools used for development. Chapter 4 outlines the development of the application, including each of the three main components of the project, the mobile GIS engine, the template, and the application GUI and describes the results of the project, including the teaching capabilities of the application. Chapter 5 describes some conclusions and opportunities for further development.

Chapter 2 Related Work

There is extensive research on the pedagogy of teaching GIS&T (Foote et al. 2012). This project builds upon this foundational research in conjunction with the current research on m-learning and micro-learning. M-learning theory itself builds upon the frameworks of more traditional distance education and more recent advances in e-learning (Park 2011).

2.1. GIS&T Pedagogy

Research into GIS&T pedagogy has focused on both the science, or theory, and technology, or application. These two main categories are manifest in the teaching methodologies that are within the research. From the science side, teaching spatial thinking has been an important area of research. From the technology side, the research focuses on how to teach the technology and have it stick, with one of the most common approaches being active learning. Active learning is “a process whereby students engage in activities, such as reading, writing, discussion, or problem-solving that promote analysis, synthesis, and evaluation of class content” (Center for Research on Learning and Teaching 2016). The focus on analysis, synthesis, and evaluation corresponds to the higher cognitive levels defined in Bloom’s original taxonomy (Seaman 2011). This definition highlights the focus on student engagement with the course content, which is a key value of m-learning (Quinn 2011).

2.1.1. *Spatial Thinking in GIS&T Pedagogy*

The concept of spatial thinking has been recognized for more than 100 years but has grown as a research topic significantly in the past 30 years (Stinton 2014). Spatial thinking is “thinking that finds meaning in the shape, size, orientation, location, direction or trajectory, of

objects, processes, phenomena, or the relative positions in the space of multiple objects, processes or phenomena” (Science Education Resource Center of Carleton College 2012).

In 2006, the National Research Council (NRC) published an extensive report on the importance of spatial thinking and on teaching spatial thinking in modern education. This report called spatial thinking an “amalgam of three elements: concepts of space, tools of representation, and processes of reasoning” (National Research Council 2006 12). The NRC report identified GIS&T as a plausible platform to teach spatial thinking. The report outlined the need for some GIS&T software redesigns to improve the capability of using it as a support system for teaching spatial thinking.

Since this report was released, GIS&T software has made significant advances. In particular, GIS&T software companies have created easy to use APIs that allow the design of custom applications with static, interactive, or animated maps (Wagner 2015). The NRC report stated that simplified user interfaces are necessary for wider GIS adoption in K-12 education. This project has a custom interface, designed for GIS&T education, which should alleviate this concern. This application also supports the use of many different GIS&T functions such as analysis, location-based services, and the viewing of attributes, among others.

2.1.2. Core Curriculum, the GIS&T Body of Knowledge, and the GTCM

Early formalized GIS&T curricula were usually in the form of technical manuals distributed with software packages. In the early 1980s, educational programs began incorporating GIS&T into their curriculum. Eventually, the National Center for Geographic Information and Analysis (NCGIA) at the University of California, Santa Barbara, the State University of New York at Buffalo, and the University of Maine defined a core curriculum, which was the foundation for GIS&T education for over a decade. One obstacle the core

curriculum faced was its limited scope, which did not cover all the topics in the GIS&T field (Kemp 2012).

The University Consortium for Geographic Information Science (UCGIS) proposed the development of model curricula that would focus on undergraduate subdomains of GIS&T. In 2003, after several years of development, UCGIS published the Strawman Report (UCGIS 2003). This report included a body of knowledge broken into 12 knowledge areas that was further subdivided into units and topics. The intention behind the model curricula project was to create an open source of curriculum objectives from which schools could create multiple curriculum paths depending on the desired outcome of the learning program. Because of the cross-disciplinary nature of GIS&T, this multi-path approach was crucial for the model curricula project to be successful (Johnson 2006).

Expanding upon the success of the Strawman Report, UCGIS in conjunction with the American Association of Geographers, pushed for the development of a full body of knowledge which included post-baccalaureate curricula units and topics. This expanded Body of Knowledge also condensed the 12 knowledge areas into 10. In 2006, the AAG published the GIS&T Body of Knowledge (DiBiase et al. 2006). Again, the emphasis in this new body of knowledge was in providing curriculum planners with groupings of educational objectives for inclusion in a degree path, course, or lesson. Despite the focus being on curriculum planners in university settings, other uses are possible. Geospatial professionals may clearly articulate their job tasks with it. Job seekers may use it to articulate their skills clearly. Accrediting bodies may use it to evaluate educational programs. There are many other potential uses from this broad collection of objectives that define the GIS&T BoK (DiBiase 2006). Since the original publishing of the GIS&T BoK, UCGIS has ported the BoK to an online database that is freely accessible to those

who want to use it. With the same purpose as the original BoK, this online format also allows for continual updates as new technologies and methodologies become part of the GIS&T BoK (UCGIS 2018).

The GIS&T BoK is the result of a decades-long process to develop curricula to help the rising generation learn the skills necessary to enter the workforce. However, as the curricula were going through a defining phase, the workforce needed similar definition and refinement. To this end, the Department of Labor's Employment and Training Administration (DOLETA) worked with geospatial industry leaders from 2004 to 2010 to define six geospatial occupations (O*NET Online 2018) and create the Geospatial Technology Competency Model (GTCM) (DOLETA 2010).

While the GIS&T BoK focused on the educational outcomes of university programs, the GTCM focused on the skills and competencies needed for geospatial workers to be successful. This distinction seems slight but is important. While the BoK focuses on the breadth of all possible skills within the GIS&T field, this model focuses on the skills necessary for defined careers within the field. This model covers a wide range of skills, including many outside the GIS&T field. Tiers 1-3 are not specific to the geospatial field but are considered the foundational skills necessary for a professional in the field. These three tiers include Personal Effectiveness Competencies, Academic Competencies, and Workplace Competencies, respectively. Tier 4 focuses on Industry-Wide Technical Competencies that are important for anyone in the geospatial field. Tier 5 divides the field into three primary sectors and lists skills necessary for each sector (DOLETA 2014).

The GTCM was intended to assist with "career guidance, curriculum development and assessment, recruitment and hiring, continuing professional development, criteria for voluntary

certification, and outreach efforts intended to communicate characteristics of the geospatial field to the public” (DOLETA 2014, 3).

In the sense that this project seeks to provide a framework in which geospatial skills can be taught, it is useful to see what tier of skills the framework supports the best.

2.1.3. Active Learning in GIS&T Curriculum

Active pedagogy in GIS&T involves “kinesthetic activities, the conscious analysis of spatial data, and reflection on learning” (West 2012, 152). Building active learning into the curriculum brings many benefits, including the claim that students learn more through the metacognition provided through active learning and that students learn more over traditional lecturing methods (Schultz 2012). There are several aspects of active learning that work well with this project. First, the kinesthetic aspect of active pedagogy works well with the touchscreen interface of modern mobile applications, allowing students to engage with the map inside the lessons directly. Second, the design of active learning is student focused. Foote (2012) emphasized that “personalized learning environments” (found in e- and m-learning applications) combined with spiral curricula, or learning cycles, create a “powerful model for learning.” A model in which tasks can progress in difficulty based on the students’ knowledge and skill during the learning process.

2.1.4. Bloom’s Taxonomy in GIS&T Curriculum

In 1956, a team of psychologists published a taxonomy designed “to measure student knowledge and understanding... [with] a convenient system for describing and ordering test items, examination techniques, and evaluation instruments.” (Pickard 2007, 46) This taxonomy became known as Bloom’s taxonomy. Over the past 50 or more years, this taxonomy has become a common part of Instructional Design and Adult Learning Theory.

The original taxonomy breaks learning objectives into six categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation. Each category requires progressively more cognitive skill on the part of the learner to achieve the desired objective. By design, a learner would need less cognitive power to meet a knowledge level learning objective than to meet an application level learning objective (Adams 2015).

The method that the taxonomy uses to identify a learning outcome's cognitive level is through the verb used in the learning objective. For example, a learning objective could be "List three benefits of a web map created with ArcGIS Online." This learning outcome uses the verb "list," which would generally fall on the lower end of the cognitive spectrum because it only uses memory recall to be achieved. This example is in contrast to a learning outcome such as "Evaluate the effectiveness of a map given a specific audience." This outcome uses the verb "Evaluate" which requires more cognitive processing than just rote memory recall. To meet this objective, the learner needs to do more than recite a list; they need to review the map, compare it against a set of criteria that may fluctuate based on the audience, and then express if the map is effective.

One of the key benefits of using Bloom's taxonomy is being able to "compare and study educational programming" (Pickard 2007, 46) across different curricula, tests, and educational programs. It also helps with curriculum planners to ensure that they are targeting the correct cognitive level of instruction with a particular activity, lesson, or course (Gold et al. 1991).

Bloom's taxonomy has historical roots in GIS&T curriculum creation as well. Gold et al. (1991) discussed designing geography curriculum through objectives in their book. They emphasized the use of Bloom's taxonomy for the following four reasons:

1. Communicate intentions of teachers more clearly to colleagues and students.

2. Provide a framework for the content and structure of a course.
3. Select appropriate teaching methods.
4. Determine an appropriate means of student assessment.

With the further definition of GIS&T curriculum through the UCGIS strawman report (UCGIS 2003), DeMers (2016) evaluated the objectives within the strawman report against Bloom's taxonomy to ensure the curriculum targeted the appropriate cognitive levels. In this evaluation, DeMers noted that the cognitive levels of the objectives in the strawman report generally fall between levels 2 and 3 (comprehension and application) and that this is an appropriate level for GIS&T education.

During the creation of the GIS&T BoK, the development included the revised Blooms taxonomy (Anderson et al. 2001). The revision altered the cognitive levels slightly and added a second dimension called "knowledge type." The new cognitive levels used in the BoK are Remember, Understand, Apply, Analyze, Evaluate, Create. The new knowledge types include Factual, Conceptual, Procedural, and Metacognitive (although the BoK excluded metacognitive objectives) (DiBiase et al. 2006, 42).

DeMers (2009) evaluated the BoK objectives against Bloom's Taxonomy as with the Strawman Report. The evaluation of the BoK noted that it contained objectives for the full spectrum of cognitive levels. The average cognitive levels across nine of the 10 knowledge areas fell between comprehension and application. The Design Aspects knowledge area had an average cognitive level between application and analysis (DeMers 2009).

This project uses Bloom's taxonomy as a standardized way to assess the potential cognitive levels of learning content provided through the project applications. By looking at the

capabilities of the lesson delivery formats in the applications, it is possible to determine what cognitive levels are possible to meet in the lessons of the applications.

2.2. M-learning for GIS&T

The process of defining m-learning can be complicated and contested. A technology-centered approach may be too limiting and miss the mark as technology changes. However, devices that lack some forms of interaction limit a purely interaction-based definition (Traxler 2009). This project uses the “just enough, just in time, just for me” model (Peters 2007). This model emphasizes bite-sized chunks of content, personalization of content, and the informal nature or “flexible learning” provided by mobile devices. This project supports all three components of this model. Another way to consider the personalization of m-learning is the concept of situated learning. Traxler (2009) states that m-learning is “uniquely placed to support learning that is personalized, authentic, and *situated*” (emphasis added). Location-based services can be used to create situated learning in which the learning experiences can change based on the environmental factors within which the learning takes place (Mountain 2012). The mobile GIS engine of this project supports situated learning as presented here.

2.3. GIS&T as a Tool to Enable Study

GIS&T is both an object of study, and a tool to enable study (Mountain 2012). Using GIS&T as a tool to enable the study of GIS&T is not new. In the early 1990s, there was an effort to build a GIS Tutor as a computer-aided learning tool (Raper 1991). In the late 1990s, Cartwright, Deakin, and McNaught (2000) outlined the creation and use of a “multimedia learning package” to teach map projections. The packages included the mathematical formulas of map projections along with corresponding visual representations of how those formulas help create the projections themselves. About a decade later, animation was used in teaching map

projections in Turkey. They explained that the use of animation was particularly effective, “because motion is often fundamental to the concept [of map projections]” (Beşdok et al. 2012, 666).

With the invention of modern web technologies, making maps interactive and user-centric has become easier (Peterson 2012). Advanced APIs and modern map resources can be combined to create map mashups that mix mapping services such as Google Maps and spatially referenced data in a map that is enlarged and manipulated by the web user (Hudson-Smith et al. 2009). One of the first examples of a map mashup was when Paul Rademacher created Housingmaps.com by overlaying a list of places available for rent listed on Craigslist over a base layer provided by Google Maps (Andersen 2007). Map mashups have grown in popularity over the past decade, and the number of mashups has grown as APIs have become easier to use, and more information is spatially referenced. While these map mashups are not designed to replace professional GIS solutions, they do provide a valuable resource for professionals and non-professionals to create and share spatially referenced information.

Many different fields of study use map mashups as a tool to teach their content. Examples of mashups in education include those used to teach about ancient Greek myths, the Roman and Byzantine empires, and the history of the battleship “G. Averof.” (Stefanakis 2012).

While mashups have been heavily used to teach subjects such as geography, science, and history, there are fewer examples where map mashups are utilized to teach GIS&T itself. This is somewhat baffling since researchers believe that the developments of map mashups are leading GIS&T education in new directions (Foote et al. 2012). Although there are fewer examples of mashups in GIS&T education, it does happen. One example of the use of map mashups in GIS&T curriculum comes from the University of New Brunswick. Around 2013-2014, a map

mashup was created specifically to teach sophomores about map projections. This map mashup allowed the students to visualize differences in lines and shapes across different map projections (Gupta, Tienaah, and Stefanakis 2014).

The application described in this thesis essentially utilizes map mashups where students can interact with layers, features, attributes, analysis tools, and other GIS&T functions to learn the lesson concept. Incorporating these mashups as core components of the lessons and avoiding highly structured exercises, allows greater flexibility and personalization of content, which is one of the major advantages of map mashups (Tate 2012).

Chapter 3 Requirements

This thesis project includes an authoring application and a lesson delivery application. Consequently, during the application planning stage, there were different types of requirements to satisfy the project goal. These requirements included general application requirements, user requirements for both content authors and learners, and lesson functionality requirements. Both content authors and end users have requirements incorporated into these applications.

3.1. Goals and Objectives

The primary goal of this research was to identify, list, and implement the GIS&T functions necessary to teach basic GIS&T principles on a mobile platform. This goal included three objectives:

1. The project sought to incorporate a wide range of GIS&T functions within the map portion of the application, including analysis, device location, attribute display, and map component widgets, among others.
2. The project was to utilize a simple authoring application that can be used by many different content authors. This application must allow the relatively simple creation of the various GIS&T components from the first objective.
3. The GUI of the lesson delivery application needs to intuitively allow learners to select lessons, navigate within lessons, and interact with lesson maps.

3.2. General Application Requirements

Although there are two applications in this project, they both had the same general application requirements. First, the applications had to be functional on a wide range of host operating systems. Without the ability to function across platforms, users would get a different

experience in the application depending on the operating system from which they are accessing the lessons. Common operating systems that the applications were expected to support include Android, iOS, MacOS, and Windows.

Secondly, both applications utilize web maps and other network resources in their lessons. Therefore, both applications required network connectivity at least some of the time to be fully functional.

Lastly, one of the critical components for the creation and viewing of lessons is the template file. This file was required to contain all of the information necessary for the lesson creation and the lesson display. It was also required to be adjustable and flexible to meet the needs of very different lessons. Chapter 4 discusses the design and implementation of the template file in more detail. The template file holds all of the data for each lesson based on the functionality included in that lesson by the content author. In addition to the template file, there must be a database that stores all of the lesson template files. This database must be accessible by both the authoring application and the lesson display application.

3.3. User Requirements

The authoring application's purpose is for a content author to create lessons for learners. This purpose necessitated unique user requirements for the content author that are different from those of the learner. Table 1 lists these content author requirements. These requirements are the key requirements for the project to be successful. There are additional features that are not listed here because they were not considered critical to the success of the project during requirements gathering. Failure to include the requirements listed in Table 1 in the authoring application would indicate that the did not meet the first and second objectives of the project.

Table 1. Content author requirements

| Req. # | Requirement |
|--------|---|
| CA-1 | The authoring application will present all of the required data of the template file logically with easy to complete fields |
| CA-2 | The template will allow the creation of all the functionality listed in Table 3 |
| CA-3 | Content authors can preview their work in the application |
| CA-4 | The authors will be able to save template field entries to a database |
| CA-5 | The authors will be able to edit existing lessons in the database to correct any errors |
| CA-6 | The fields within the template need to be well named or provide any documentation necessary to ease the creation of lessons |

The requirements for the lesson display application focus on learner needs. Table 2 lists these requirements. As with Table 1, additional features are not in this list because the success of the application was not dependent on the additional features. In essence Table 1 and Table 2 can be considered the basic requirements for the applications to reach the goals of the project.

Table 2. Learner requirements

| Req. # | Requirement |
|--------|---|
| L-1 | There will be a selection screen from which end users can select any lesson |
| L-2 | The application will allow easy navigation within a lesson and across lessons |
| L-3 | End users will be able to navigate the map components of lessons with the typical gestures of their touchscreen device |
| L-4 | End users will be able to record data to feature services when required by a lesson |
| L-5 | The end user will be able to turn off the application's access to their location if desired |
| L-6 | The end user will be able to customize course content based on their location and other analysis variables they can select (For example, buffer distance) |
| L-7 | The user will be able to download lessons for offline learning |

Table 3 lists the required functionality that the lessons must support. This table splits the functionality between general lesson functionality and GIS&T lesson functionality. General lesson functionality includes data, functions, and abilities that lessons on any topic may require.

Table 3. Required lesson functionality

| Functionality | Description |
|---------------------------------------|---|
| <u>General lesson functionality</u> | |
| Information | Lesson title, description paragraph, tags, the category of the lesson, and lesson objectives, among others |
| Lesson content | Headings, subheadings, and paragraphs |
| Images | Images with captions to help explain the content. Include animation, if needed |
| Knowledge Checks | Questions the test knowledge comprehension, such as multiple choice, true/false, or fill in the blank |
| Pages | Lessons should be able to be split across multiple pages |
| <u>GIS&T lesson functionality</u> | |
| Web maps | The ability to load web maps. Included in this functionality is the ability to toggle layers within the web map |
| Symbology | The ability to adjust symbology in a web map |
| Attributes | The ability to show feature attributes in either an attribute table or a pop-up |
| Legend | The ability to show a legend |
| Metadata | The ability to show metadata for the web map |
| Widgets | The ability to include common map widgets including basemap toggle, GPS toggle, home button, north arrow, and scale bar |
| Location tools | The ability to utilize the end user's device location |
| Analysis | Add the ability to run analysis on the map layers as part of the lesson. Within the GIS&T body of knowledge, analysis is a core component. Therefore this functionality is critical |
| Analysis Interaction | At least one of the analysis inputs should come from learner interaction. This interaction can be drawing a feature, selecting a feature, using the device's location, adjusting analysis parameters, or a combination of these |

For example, a lesson on tables may not need the more advanced GIS&T capabilities, but would still likely include text, images, and knowledge checks. GIS&T lesson functionality

includes data, functions, and abilities that lessons covering GIS&T topics may require. It is important to note that although it is called required functionality, a content author is not required to include all this functionality in any given lesson. For example, a lesson that discusses symbology may not use analysis functionality. However, analysis functionality is still a required component for those lessons where it would be needed.

3.4. Design Principles and Choices

There were many different frameworks and platforms considered for the development of the applications in this project. The first decision in the process of determining a framework was if this would be a web application or a native application.

3.4.1. Web Application Framework Considerations

One of the primary benefits of web applications is the browser-based nature of the application. The utilization of a browser allows the application to be cross-platform by nature. Because of this feature, developing a web application that a learner could access from a mobile device was under consideration at the beginning of the project.

There were two web application frameworks considered for this project. Esri's Story maps, Esri's ArcGIS API for JavaScript.

The Story map format is a templated web mapping application that incorporates maps, text, images, tables, and charts in a chronological method to tell a story. For this project, that story was going to be an educational lesson using the story map template. However, at the time of determining the framework for this project, the story map application framework did not allow an end user to perform analysis within the story map without considerable customization. This

customization would require a content author to know some coding to include any analysis functions in their lesson.

The second format considered was Esri's ArcGIS API for JavaScript. This API includes all of the GIS&T functionality required in the applications but does not have a method for working offline. This limitation means that any content author or learner trying to write or take a lesson must be connected to the network at all times to do so. This limitation is the challenge that all web frameworks faced, which is why a native application framework.

3.4.2. Native Application Framework Considerations

Many native coding tools are available for cross-platform applications like those in this project. These frameworks include, but are not limited to, Adobe PhoneGap, Apache Cordova, Qt, and Xamarin.

Because of the extensive mapping ecosystem that exists with Esri's ArcGIS Online, the project targeted development frameworks that work with this ecosystem. Esri creates APIs for both Xamarin and Qt, which provide all of the required GIS&T functionality. Because of the similar functionality between the Xamarin and Qt APIs created by Esri, either option would be sufficient for the needs of this project.

Esri has a development IDE for the Qt framework called AppStudio for ArcGIS. This IDE comes with example code and extensive documentation for the GIS&T functionality built into the Qt Creator IDE. The Qt framework also has a module that allows development of applications in the QML language. QML is structured in a similar way to JSON and is designed to treat QML objects, called types, in a similar way to JavaScript objects. The QML language also allows in-line JavaScript code to manipulate the structure of the application. The project author chose to use the Qt API and the AppStudio IDE based on existing knowledge and

familiarity with JavaScript and the support for this knowledge in the QML language. The remainder of the application development process used QML and JavaScript as the primary development languages.

3.4.3. Database Considerations

Since both applications in the project heavily depend on the template file, it was important to determine the right way to format and store it. As mentioned, QML is designed to operate with JavaScript, objects. The QML framework, therefore, has native functionality for reading and updating JavaScript objects and storing them in JSON format, which is the native storage format of JavaScript. JSON was the ideal storage format for the template file.

The JSON format uses hierarchy to manage nested objects and data. The highest level in the hierarchy of the template file was for general lesson information, including lesson title, lesson description, and tags, among other data. The second level in the hierarchy of the template file stores the lesson pages. Then within each page section of the template file are the components the author creates for that page. The number of pages is dynamic and can vary from lesson to lesson. The type of components and the number of components within a page is also dynamic and will vary from page to page and lesson to lesson.

The structure of how the template file stores each type of lesson component was part of the design of each component during development. Some of these components are simple, with relatively little data stored within that component. An example of this simple component type is the Heading component, where it is only the component type, component number and the text of the heading stored in the template file. By far the most complex component is the mapping component. It includes fields for web maps, analysis, interaction types, and map widgets, among others.

Requirements CA-4 and CA-5 (as listed in Table 1) needed a database that also works natively with JavaScript objects and JSON. There are a few databases that work in JSON structure, but a very popular one is MongoDB. This database treats each JSON object sent to it as a “document” and has a query language designed to find documents and parts of documents as needed. Accordingly, MongoDB was the selected Database for this purpose. A cloud database using MongoDB was the selected repository for the lesson template files.

The authoring application builds and edits the template file as directed by the author during lesson creation. Then, when ready, the lesson author can save the template file to the online database. The authoring application sends the template file to the database over a network connection where it is stored in JSON format until it is retrieved. From this cloud database, the authoring application downloads the existing lessons for editing and adjusting. The lesson display application also downloads the lessons from the database but gets a subset of lessons that the author has determined are ready for learners.

The lesson delivery application also required a local database to allow for offline lesson access (requirement L-7, Table 2). For this purpose, a MySQL database within the lesson display application stored the JSON of the downloaded lesson template file. This MySQL database can also store information for future functionality, such as lesson progress and completion.

3.4.4. User Interface Design

The design of the user interface for both the authoring application and the lesson delivery application is a critical consideration. By working with the AppStudio for ArcGIS, some code samples were identified that allow for a consistent look and feel for the application. These code samples in conjunction with some other wireframing provided the GUI model which the application emulates.

SoloLearn is a company that develops applications that teach learners various programming languages. Their application user experience (UX) was the model for the lesson viewer application (Figure 1). The SoloLearn apps use different teaching components that form the basis for many of the components in the applications of this project. Examples of these components include headings, paragraphs of explanatory text, images, knowledge checks, and interactive coding sandboxes. The lessons in this project are not coding related, so an interactive map replaced the interactive coding sandbox. There are other apps available with similar functionality, but SoloLearn was the primary model for this project. Not all functionality of the SoloLearn apps became part of this project. For example, the community chat functionality where students can share their challenges and discuss solutions was not a requirement for this project but future development efforts can include this functionality.

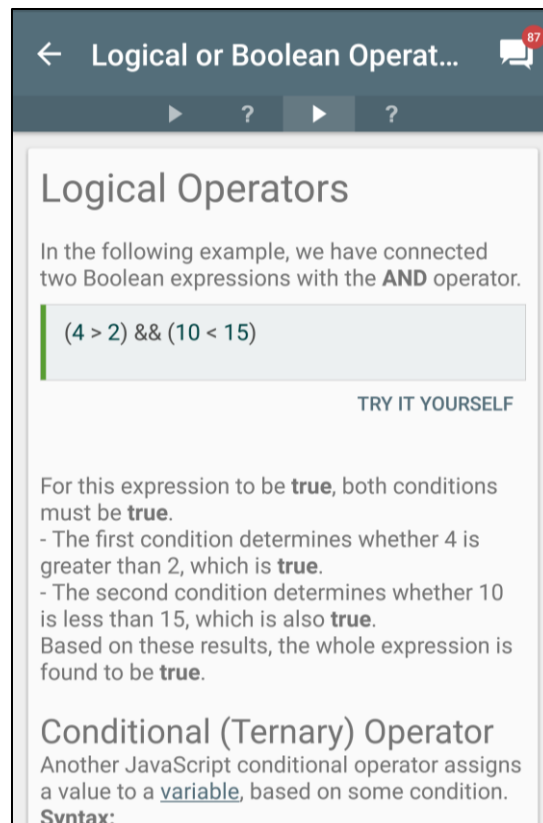


Figure 1. Screenshot of the lesson GUI for the SoloLearn sample application

3.5. Assessment Criteria

The requirements defined for the application are one set of criteria for measuring success. However, other criteria also determined the success of this application. The template file and content creation is a crucial part of this application. As such, the application required content written to cover several aspects of GIS&T using the same template. Therefore, lessons to evaluate the effectiveness of the applications utilized objectives defined in the GIS&T Body of Knowledge (DiBiase et al. 2006).

The GIS&T Body of Knowledge was created in response to the need to develop a set of curricula that met the needs of the wide range of student constituents within the GIScience field (Dibiase et al. 2007). The Body of Knowledge provides objectives that educators can use to guide the development of more detailed lessons in GIS&T topics. The sample lessons used for evaluation took this approach, starting from objectives listed in the GIS&T body of knowledge. Evaluation criteria include ease of lesson creation and the ease at which a learner can access the lesson interactivity. Looking at the effectiveness of the application as a teaching tool is outside the scope of this project, but would be a good recommendation for further research.

Chapter 4 Application Development

As discussed, two applications are part of this project. This chapter focuses on how the applications work. For the discussion of the authoring application, this takes a look at how to create a lesson and any work done before using the application. For the discussion of the lesson display application, this takes a look at how a learner uses the application to go through a lesson. The last section of this chapter shares what software components are part of these applications and their associated costs and licensing.

4.1. Authoring Application

For a content author who plans to create a new lesson on a GIS&T principle using the authoring application, there are two primary steps. The first is to complete some prework specifically for the GIS&T components, and the second step is to create the lesson in the authoring application. For the prework, the author should design the lesson, create any web maps, and create the geoprocessing services if needed.

4.1.1. Lesson Creation Pre-work

The lesson design starts with a topic and then a detailed structure for how to teach the topic through the components available. This design includes the maps and geoprocessing services used in the lesson.

If any of the web maps do not already exist, the content author creates these web maps and stores them in ArcGIS Online. These web maps should include the basemap, feature layers, and symbology desired by the content author to demonstrate the lesson concept. Ideally, the data shown on the map is worldwide. This consideration would allow a learner to see features close to their location, making the lesson “situated.” Esri’s ArcGIS Online, ArcGIS Pro, or ArcMap can

all be used to create the web maps used in a lesson. The only specific requirement is that ArcGIS Online stored the web maps.

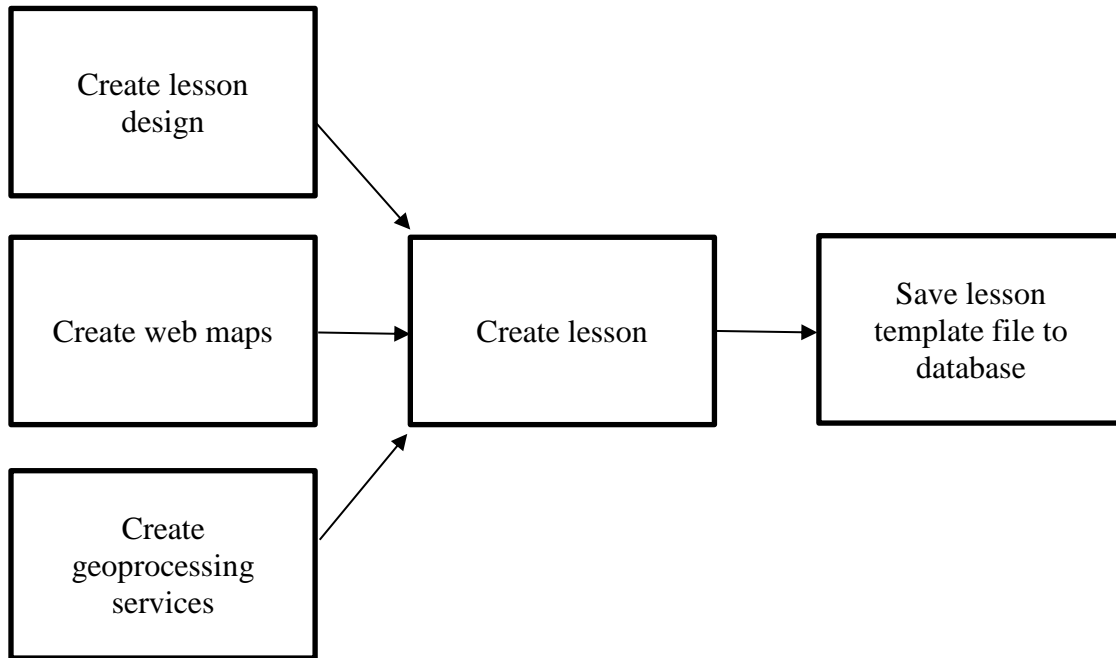


Figure 2. Lesson creation workflow

In addition to creating the web maps used in the lesson, any analysis needed for the lesson must come from a geoprocessing service. Any geoprocessing service used must be on a server without being behind a firewall. The learner application can only access analysis functionality through the use of geoprocessing services on a server. For this project, a personal server running ArcGIS Server hosted these services. Either Esri's ArcGIS Pro or ArcMap can create the geoprocessing services used in this application.

The authoring application picks apart any geoprocessing service to know how to work with it during a lesson. This includes which parameters the learner sets and which parameters are static. For the application to know this, the content author must set the geoprocessing

parameters properly during service creation. Each analysis parameter within a geoprocessing service has three key parts that the content author needs to set properly.

The first is the name of the analysis parameter. This name is what will appear to the end user and therefore needs to be intuitive and helpful. Each parameter is also set to be required or optional. The content author needs to pay attention to this parameter to make sure the parameters set to required are truly required. For simplicity of lesson development, each geoprocessing service should perform only one task within a map. Therefore, optional fields do not appear in the lesson display application. The last parameter the content author sets properly for each field is the value. Each field can have a set rigid value baked into the service, or the learner can set the parameter during the lesson. The fields set by the learner are called user input in the service creation options. For user input parameters, they are either values or features. The learner can provide features as an input by the different methods of geometry interaction available in the authoring application. These options include device location (point), draw point, draw line, draw polygon, or select feature. For value fields, if the author sets them to user input, the author must select a unit of measure and include it in the name of the service. The content author can set more than one parameter as user input when creating the geoprocessing service. Table 4 shows a simple example of a geoprocessing service with its parameters and settings.

Table 4. Sample geoprocessing service parameters

| Parameter | Name | Required? | Value |
|--------------------------|----------------|-----------|---------------------|
| In_features | Input_Feature | Yes | User input |
| Out_feature_class | Out_feature | Yes | Static (set by app) |
| Buffer_distance_or_field | Distance | Yes | User input (meters) |
| Line_side | Line_side | No | -- |
| Line_end_type | Line_end | No | -- |
| Dissolve_option | Dissolve | No | -- |
| Dissolve_field(s) | Dissolve_field | No | -- |
| Method | Buffer_method | Yes | User input |

4.1.2. Authoring a Lesson in the Authoring Application

With the pre-work complete, the content author can begin lesson creation within the authoring application. When the application starts, the content author has the option to edit an existing lesson pulled from the database or create a new lesson. For a new lesson, the first fields shown on the create lesson page are the lesson title, lesson description, lesson tags, lesson category, and lesson status. By default, the lesson status will be draft, which will prevent it from being available in the lesson display application.

After the content author fills in the initial fields, a new page is shown, with a toolbar that serves as the primary navigation for lesson creation (Figure 3). The first option along the toolbar is the selection box which contains all of the component types that are selectable by an author. The second option on the toolbar is the page navigation, where the author can add pages, or move between existing pages of the lesson. The third option on the toolbar is the lesson preview button. This button opens the window in a separate window so the author can see how the lesson looks. The last button on the toolbar is the save button, which sends the template file to the cloud database for storage and later retrieval.

To add a component to the lesson, the author selects the component from the drop-down list on the toolbar and clicks the add component button. With the selection of a component, the fields associated with that component appear in the configuration screen. The author can then fill in the information required for that component and add new components. The order of the components in the configuration screen is the same order as in the final lesson.

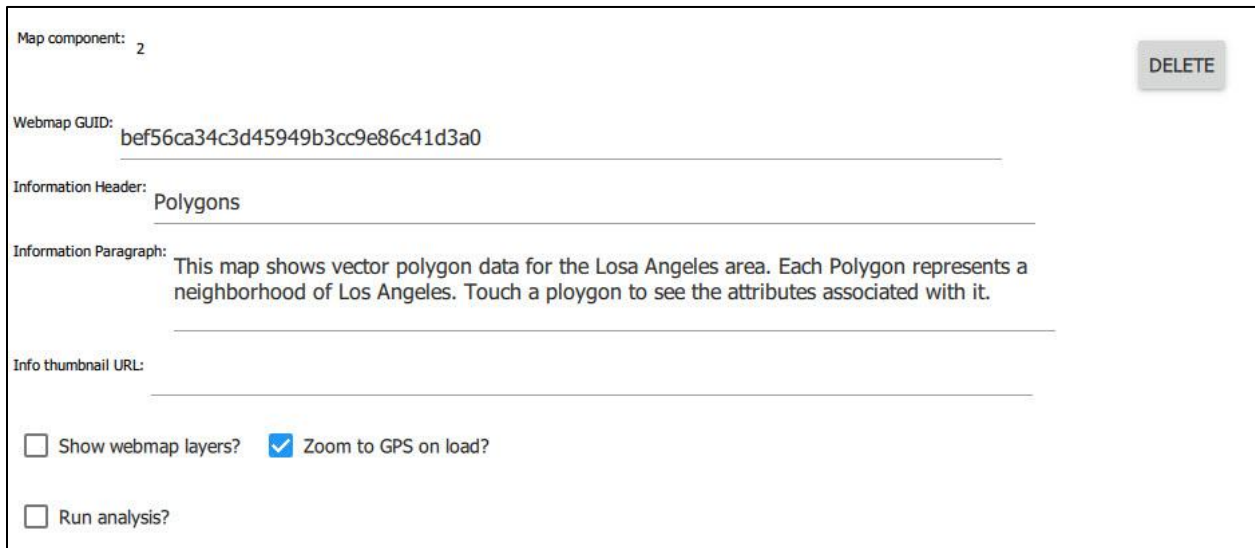


Figure 3. The authoring application lesson navigation toolbar and configuration screen

Each component in the configuration screen comes with a delete button that will remove the component from the configuration screen and the lesson. When an author deletes a component, the component fields disappear from the configuration screen, and an undo button replaces the delete button. Next, to the undo button in this half-deleted state is a permanent delete button that will remove the component completely. While the component is in this half-deleted state, it will not appear in the lesson preview or the final lesson, but the content within the component fields remains in the template file until the author permanently deletes the component. This half-deleted state allows an author to preview the lesson without a built component and avoid a potential rebuild of that component. Each component also has a reorder button that allows the author to change the placement of the component within the page.

When an author completes a page, they can create a new page. The new page clears the configuration screen and allows the author to start adding components to this page. Functionally, there is no limit to the number of pages within a lesson, and there is no limit to the number of components within a page. However, to qualify as micro-learning, the lessons should be relatively short. The authoring application does restrict the author from creating a new page if the current last page of a lesson is blank.

An author includes GIS&T functionality by adding a map component (Figure 4). The map button component includes all of the fields necessary for a single web map and its associated options for interaction. These options include those in the GIS&T section of Table 3. If another map is necessary for the lesson, the author adds another map component to the lesson and complete the required fields in the lesson configuration screen.



Map component: 2 DELETE

Webmap GUID: bef56ca34c3d45949b3cc9e86c41d3a0

Information Header: Polygons

Information Paragraph: This map shows vector polygon data for the Los Angeles area. Each Polygon represents a neighborhood of Los Angeles. Touch a polygon to see the attributes associated with it.

Info thumbnail URL:

Show webmap layers? Zoom to GPS on load?

Run analysis?

Figure 4. The fields of a map component which provide GIS&T functionality in a lesson

At any time in the development process, an author can preview the lesson and the built components by clicking the preview button (Figure 5). Requirement CA-3, in Table 1, stated that the content author needed the ability to preview their work within the authoring application. By design, the preview functionality and GUI in the authoring application mirror the functionality and GUI of the lesson display in that application. This approach minimized the development time of the lesson display application by utilizing existing code.

The workflow for editing an existing lesson is very similar. A content author would select the existing lesson from the list of lessons when the authoring application opens. This choice will bring up the same initial screen, where the editing of the lesson information such as title and

lesson description takes place. Then, as with creating the lesson, the toolbar and existing components appear in the configuration section, and the author can make changes.

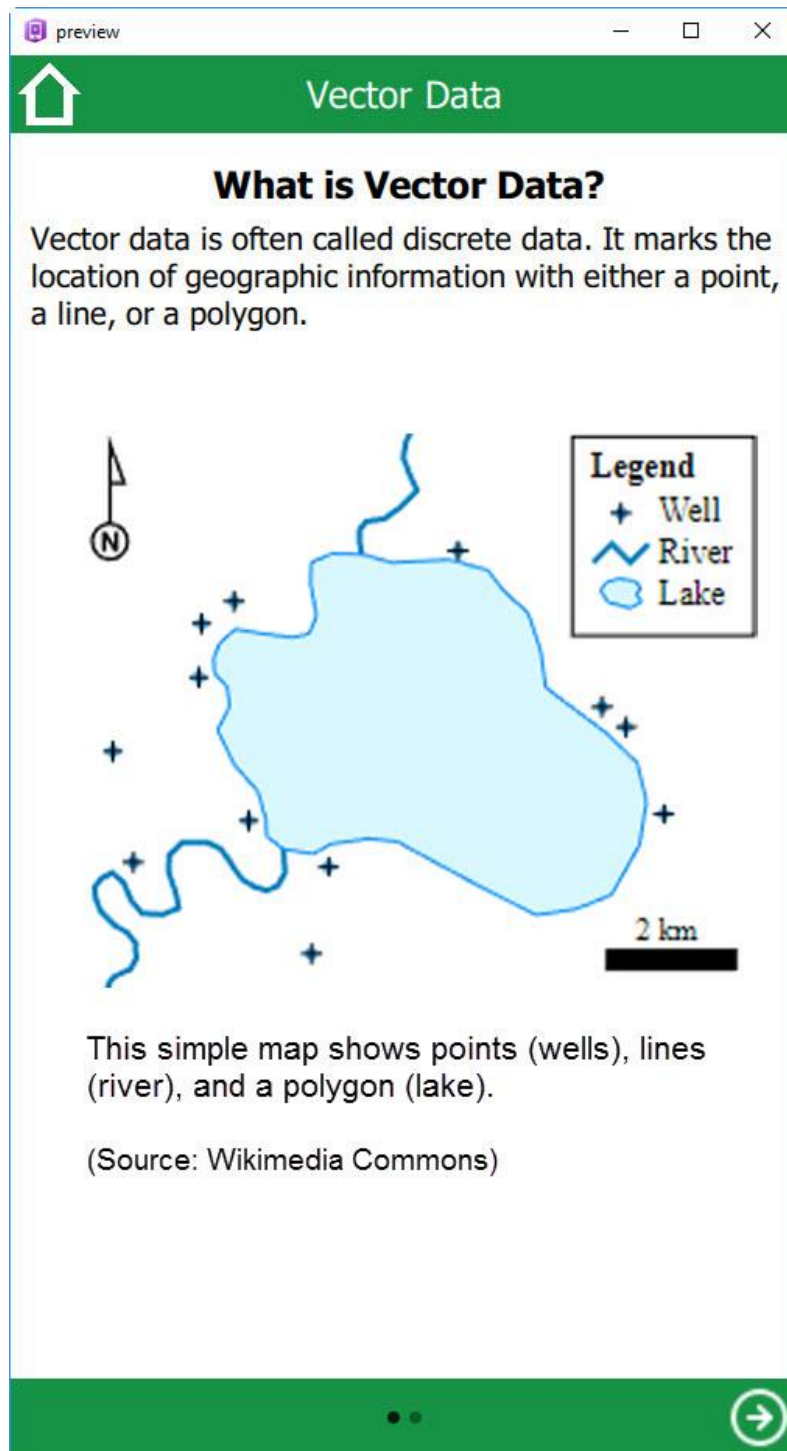


Figure 5. The authoring preview mirrors the actual lesson display for the learner.

4.2. Lesson Display Application

The lesson display application has a simple workflow as shown in Figure 6. At a high level, the learner selects a lesson and then reads the lesson and interacts with the map to learn the GIS&T concept.

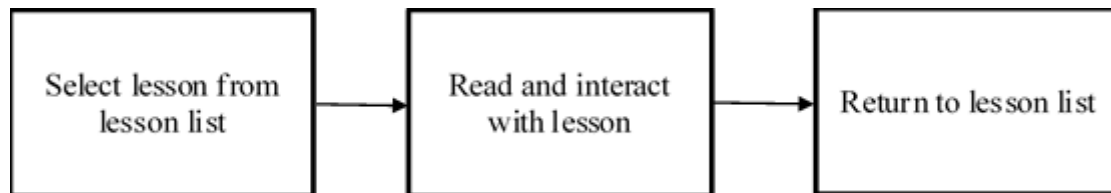


Figure 6. Learner workflow for lesson display application

When the application opens, it loads all of the existing lessons from the database. The list of lessons shows a card for each lesson. This card includes the lesson title, a lesson description and a thumbnail graphic of the lesson content. When the lesson is selected, the application retrieves the whole lesson template file from the database and loads this. The lesson display functionality is identical to the preview functionality of the authoring application.

The lesson display application also has the ability for a user to download a lesson for offline use. If a lesson is available for offline use, a download icon appears in the corner of the lesson card in the lesson selection screen.

The GIS&T functionality of the lesson display application is one of the critical components of the project. This functionality appears within the lesson through a map button. This button opens a window with a map and loads the web map created by the content author. Loading the web map in the display application keeps the same basemap, layers, and symbology.

On the left of the map page is a side pane for additional information and functionality (Figure 7). This drawer opens on a portion of the screen and is composed of several sections. The first section displays information about the map and the author's explanation for why this map is

in the lesson. The second section shows the attribute table. This section is not available by default but appears if the author enables it. For simplicity, an attribute table can only be active for one feature layer for each map. The third section is for analysis. This section is not visible unless the author enables it. The fourth section is for map metadata.

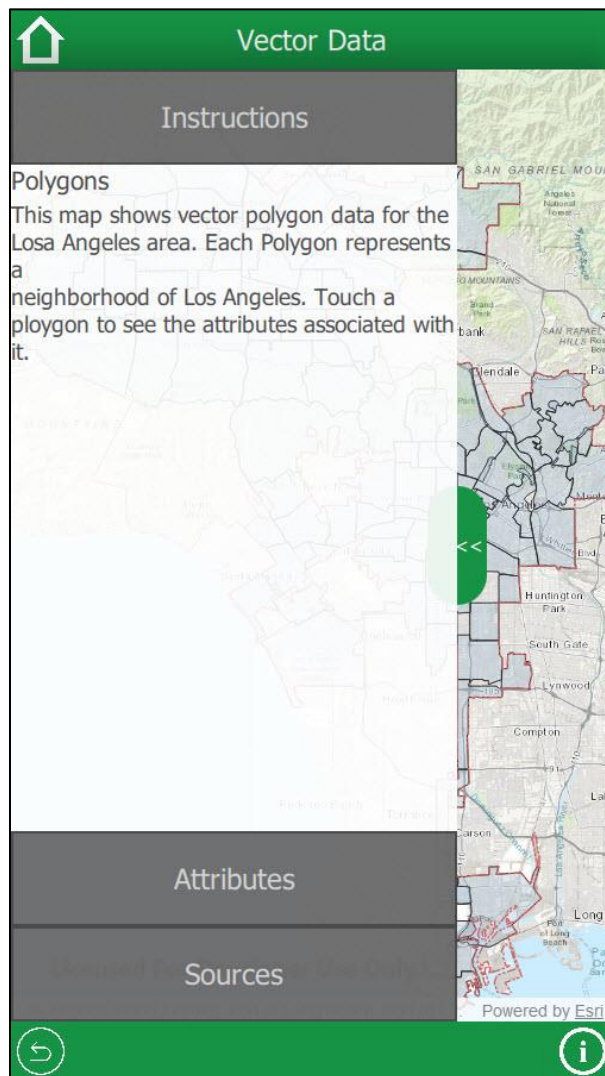


Figure 7. The side pane of the map component in the lesson display application.

The analysis section shows the parameter fields that are configurable by the learner. Next, to each field, an information button explains how to use the field. If the analysis is configured to work with a selected feature, the device location, or a drawn feature, then an

explanation for that part is given, with instructions on how to select a feature, turn on the device location, or draw a feature, respectively. At the bottom of the section is a button that runs the analysis.

When the learner presses this button, the application confirms that it has all of the data necessary for the required fields of the geoprocessing service. The application then sends this data to the geoprocessing service using a REST API request. The server runs the analysis and returns the results to the application. The application parses the results and plots them on the map accordingly. After the analysis is complete, the run analysis button becomes a reset button. When the learner presses the reset button, all of the analysis results disappear from the map. Then, the parameters return to their original setting for the learner to try again. Since a server runs all of the geoprocessing services, there are no costs for running analysis.

4.2.1. User Vignette

The following user vignette explains how a learner would use the application to learn about proximity analysis. This lesson for proximity analysis is just a sample of what is possible.

When the learner opens the application, a list displays of all of the possible courses available to the learner. The learner selects the Proximity Analysis lesson from the list. A new screen appears with the title Proximity Analysis at the top. An introductory paragraph explains what a proximity analysis is and shows an example in a static image. The learner swipes to the next page after reading through this content. On the next page, there is a section called, types of proximity analysis with a table of the three different types of proximity analysis and when to use each type. The learner swipes to the next page after reading through this content. On the next page, one of the types of proximity analysis, drive time analysis, is explained in detail. At the bottom of the page, there is a “Try it” button.

The learner taps the “Try it” button and opens a map page. On this map page, they see a map with points surrounding a pulsing point representing their current location. On the left is a control panel that is either open, or the user opens it by tapping it (depending on the size of the mobile device screen). Within the control panel, there is an explanation section, an analysis section, and a credits section. The explanation section explains that the points on the map represent fast food restaurants in the U.S. and explains that the learner can run an analysis to see which restaurants are within a 5, 10, or 15-minute drive from their location. The analysis section shows the options for drive time, 5, 10, or 15 minutes with instructions to select one and click the analysis button.

The learner selects an option and clicks the analysis button. If the learner is on a small screen device, the control panel will close. On the map, a status symbol indicates that the analysis is in progress. Once the analysis is complete, the drive time polygon displays on the map and a popup table displays the results with a table of all fast food restaurants within the selected drive time. After completing the drive time analysis once, or several times, the learner can return to the lesson.

When the learner swipes to the next page, there is a checkpoint activity with two questions about the drive time analysis. The learner answers the first question, a true or false question, successfully and hears a cheer. The second question, a multiple choice question, is missed and the learner hears a buzzer indicating that they answered incorrectly. They have a chance to retry the question before moving on to the next page.

The learner swipes to the next screen where another type of proximity analysis, radius analysis, is explained in detail. At the bottom of this page, there is another “Try it” button which opens a map that allows the learner to try a radius analysis. Similar to the drive time analysis,

when they return to the lesson, the next page has some checkpoint questions that the learner must answer before moving on to the next section.

The next page of the lesson goes through a similar process with the third type of proximity analysis, nearest neighbor. After completing all sections and checkpoints, there is a final checkpoint with a few more questions about proximity analysis. After passing the checkpoint, the learner hears another cheer and returns to the home screen with the list of lessons. Now there is a green checkmark next to the proximity analysis lesson indicating that they have completed that lesson.

Chapter 5 Conclusions

The project conclusions cover three areas. The first is the type of content that this project can support and the type of content that it cannot. The second area is learner mobility when using the lesson display application. The third is the ease of lesson creation for content authors. In addition to these primary conclusions, the last section addresses opportunities for further application development and research.

5.1. Lesson Content Considerations

The goal of the project is to provide a framework with which to teach any GIS&T topic. The emphasis of this framework is hands-on experience through a GIS&T sandbox that allows students to learn the concepts in a situated learning environment without needing advanced GIS&T software on their mobile device.

By providing content that is accessible on any device, this framework is suitable to support content for all levels of learners, including k-12, university level, and adult learners. For each audience, the lesson authors will need to keep the needs of the audience in mind and scale the lesson content accordingly. For example, content for a learner in middle school would not be the same as content for a university student or a professional trying to learn GIS&T principles. Keeping the audience in mind when developing the curriculum for this application framework would be an important part of ensuring the lessons are effective.

It would be beneficial for curriculum developers to draw from the GIS&T BoK or the GTCM to guide their curriculum in this framework. Based on the revised Bloom's taxonomy used in the GIS&T BoK, not every objective is effectively taught in this framework. As discussed, the learning objectives within the BoK fall into the different cognitive levels of Bloom's taxonomy, but also within the three knowledge types of the revised taxonomy. These

three knowledge types are factual, conceptual, and procedural, which is the what, why, and how of GIS&T.

The lessons that these applications are capable of supporting focus almost exclusively on the factual and conceptual knowledge types. The applications support this using text, images, knowledge checks, and interactive maps to explain the factual and conceptual knowledge of a given topic. Although the interactive maps sometimes included the procedure through the use of analysis, the procedure is a tool to explain a concept, rather than focusing the lesson on the procedure.

This does not mean that procedural knowledge cannot be taught using this application. Providing a series of steps explaining how to complete a given task within GIS&T software is completely possible in this framework. However, the goal of the framework was to provide all of the resources necessary for that training within the mobile device. Instructions on how to complete a task using software that likely will not run on the mobile device would not meet this goal.

Within the realm of GIS&T functionality, many components occur outside a map. These components include python scripting, statistical analysis on attributes, and SQL queries within databases, among others. The interactive sandbox of this application focused on map-related activities. For all of these components that occur outside a map, these applications did not provide sandbox functionality, which was a core goal of the project.

5.2. Learner Mobility

Being able to learn in any place, at any time, on any device was a key focus of this project. The applications in this project show that this is possible with one key exception: the ability to work fully offline.

For offline content, the text, questions, and images within a lesson are easy to download and store on the mobile device. The problem with offline lessons comes with the GIS&T functionality. This functionality works using web maps and geoprocessing services hosted online. Esri's AppStudio framework has built-in functionality to work with offline maps and data as do other mobile GIS application frameworks (Esri 2018; Mapbox 2018). However, this functionality is only practical for a predefined area and scale due to storage limitations in mobile devices. Predefined map areas and scales will not work if the goal is situated learning in any place, with any device. Some lessons, which do not fully utilize the situated learning afforded with these applications are downloadable for offline use. The maps in these lessons, however, are little more than interactive images explaining a concept using an abstract area with which only some learners will be familiar.

The geoprocessing services used to teach geographic analysis and to perform other tasks in these lessons is also subject to offline limitations. Esri's ArcGIS Runtime tools allow offline geoprocessing for a subset of all geoprocessing tasks. Furthermore, these tasks are limited to Windows and Linux platforms. This limitation negates the "any device" component of the project goal. The applications in this only use online geoprocessing services to maximize the number of devices that learners can use.

The ideal in situated learning is utilizing a familiar space as part of the learning process. This approach connects the unfamiliar content in the lesson with the existing experience of the learner in a familiar geographic context. This existing experience of the learner is considered a valuable resource for learning (Ota et al. 2006). By having limited options for offline lessons, some learners will not be able to have a fully situated learning experience. The ubiquity of wireless connections ideally minimizes the number of learners who cannot have this level of

learning engagement. Regardless, the limitation of offline access is a direct risk to the success of this project.

5.3. Ease of Lesson Creation

The purpose of creating an authoring application was specifically to ease lesson creation for content authors. If content authors are unable to create lessons without advanced training, it will significantly reduce the versatility of the applications. The GIS&T Body of Knowledge shows that there is a vast range of knowledge and skills within the GIS&T field. The range of knowledge and skills is so vast that there are no experts in all areas. This statement is demonstrated by the use of multiple subject matter experts in the creation of the Body of Knowledge, instead of a single expert who knows the whole (DiBiase et al. 2006, 37). It takes a team to compile education resources on such a vast Body of Knowledge; hence, the importance of making the authoring of lessons easily accessible to GIS&T experts of all backgrounds.

The authoring application combined with the fully functional preview offers a quick method for a content author to write lessons with text, pages, images, and checkpoints. The complexity of lesson creation comes when incorporating GIS&T functionality. When adding GIS&T functionality, the content author needs to start with creating a web map. The creation of a map should not in itself be a challenge, but finding and incorporating data that allows for situated learning is more difficult. For most students to understand how GIS&T applies to their location, the data needs to show something at their location. Creating a map that focuses only on one geographic area detracts from the ability to incorporate learner experience as stated previously.

Once the map exists, there are a plethora of options available for how the lesson incorporates the map. Are there pop-ups? Should the attribute table be accessible? Should the learner have access to turn off layers? Should the learners be able to change the symbology? Is

the device location important? At first glance, there could be a tendency to say yes to all of these questions, but that could introduce cognitive overload to the learners if they need to accomplish too many tasks within a single map. Content authors need only to include the functionality necessary to teach the concept intended in a given lesson.

If the content author needs to include analysis functionality in their lesson, they need to create the analysis in a single task and publish that analysis as a geoprocessing service using ArcGIS Desktop as the publisher and ArcGIS Server as the service host. Using geoprocessing in this way introduces some complexity that is not part of other GIS&T courses where learners can conduct back-to-back analysis tasks to accomplish the end goal. With this method, the author needs to chain together all of the geoprocessing tasks into a single analysis task before publishing to the geoprocessing service. Content authors then need additional knowledge of model builder and publishing geoprocessing services to create lessons for learners in this application. For some content authors, knowledge in these areas already exists. For others, training is necessary.

The authoring application makes lesson creation easier by using templates and components. Much easier than having to program each lesson by hand. It also provides a framework for a much larger and more dynamic set of lessons available to learners. However, even with the template based functionality provided by the authoring application, the knowledge necessary to create lessons is substantial.

5.4. Further Work

The results of this project provide a viable framework to develop interactive mobile GIS&T educational lessons. There is still room for improvement both with further research on this educational method and development of additional functionality in the application.

5.4.1. Additional Research Opportunities

The framework presented in this project focused on situated mobile learning where learners can interact with GIS&T functionality in a geographical area familiar to them. Based on existing research in mobile learning, this could be an improvement over current methodologies in teaching GIS&T concepts. However, removing the procedural knowledge from the curriculum may likely reduce the resulting skillset of learners over existing methodologies. Further research on the efficacy of this method over other teaching methods in GIS&T education is an obvious next step.

Another research opportunity from this application comes from another key benefit of this educational approach. In the lesson display application, the learner has all of the software they need to complete the lessons within the lesson display application itself. As a learner, there is no need to install GIS software or have an account with any organization to complete the lessons. Does this open up opportunities for learners who otherwise might not learn these concepts?

5.4.2. Further Application Development

The applications in this project provide a functional framework for GIS&T education. There are many different ways to make enhancements to this functionality.

As discussed, one of the main limitations in making this framework capable of teaching all of the objectives in the GIS&T BoK is the lack of support for procedural objectives. There are extensive tools available for creating web-based simulations of complex software. Tools such as Ancile uPerform and Adobe Captivate allow the content creator to simulate a software environment with the intent of teaching procedural knowledge without having the software open or even installed on the device showing the simulation. By incorporating the ability to show

simulations within the framework, it would open up many more avenues to develop content for every objective in the GIS&T BoK.

One of these enhancements is stringing together lessons to develop learning plans for related functionality. Potential learning plans could include basics of the vector analysis, raster analysis, and cartography, among others. Each learning plan would include a path through existing lessons.

Other enhancements include usability improvements within the lesson selection screen. The first of these is the ability to track progress within lessons and return to where a learner left off when they return to a lesson. Another one is the ability to search lessons based on titles, keywords, or lesson content. Also, the ability to filter content by category or knowledge area. Another usability enhancement includes marking lessons as favorites for quick recall later.

From a social perspective, Chapter 3 mentioned a chat functionality to discuss the lesson with peers. The ability to share a lesson or a lesson result through standard social channels could be a useful enhancement. Adding gamification where learners can earn points for lesson and learning plan completion would be another great social enhancement.

From a GIS&T perspective, the already mentioned sandbox functionality for knowledge areas outside of the map would be beneficial. Also, the ability to conduct a series of analysis functions in series, similar to how it would appear in desktop software, could help address the procedural knowledge gaps in this projects approach. Lastly, the ability to incorporate 3D scenes and data into lessons would be an important enhancement.

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