Teaching with GIS: Developing a project-based framework to teach civil engineering using software

Dr. Kevin A. Waters P.E., Villanova University

Assistant Teaching Professor in the Department of Civil and Environmental Engineering at Villanova University with a specialty in water resources engineering and GIS.

Dr. Virginia Smith, Villanova University

Dr. Smith is an Assistant Professor of Water Resources in the Civil and Environmental Engineering Department. She received her PhD studying hydrology, fluvial geomorphology, and sediment transport at the Jackson School of Geosciences at the University of Texas at Austin (UT). Prior to earning her PhD Dr. Smith received a master's degree in civil engineering from UT and her BS from Georgia Institute of Technology in civil and environmental engineering. After finishing her graduate work Dr. Smith worked in international development in Asia, the South Pacific, and Afghanistan, overseeing water and natural resource management projects. Since starting at Villanova University Dr. Smith has leveraged her experiences in her research focusing on rivers, floodplains, and flooding dynamics, particularly in urban settings. She also has several funded research projects investigating sediment transport into and through green stormwater infrastructure. She is the winner the of the Early Career Award from the University Council on Water Resources (2020) and the Villanova College of Engineering Excellence in Teaching Award (2021).

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Abstract

Geographic information systems (GIS) technology is a platform for creating, managing, analyzing, and visualizing the data associated with developing and managing infrastructure. Faculty in the Department of Civil and Environmental Engineering at Villanova University have developed a project-centric course focused on the application of GIS within the various disciplines of civil engineering. Applications of GIS are highlighted as the course steps through different phases of a civil engineering infrastructure project, including planning, data collection, environmental analysis, design, construction, and data collection for operations and maintenance. ArcGIS Pro software is used to teach core civil engineering topics throughout these project phases such as zoning requirements and calculations, elevation surfaces, watershed delineation, earthwork volumes, and roadway profiles. Thus, the course covers basic principles to facilitate a working knowledge of GIS, but also allows students to tap into the data revolution, leverage large spatial datasets to create sustainable designs, make informed decisions, and educate project stakeholders in innovative ways through graphical communication. A variety of active-learning techniques are utilized in the course, following a hierarchy where activities progressively increase in level of complexity and instructor guidance. Interactive demonstrations in the software introduce concepts and GIS tools, then scripted tutorials require students to use GIS to work through a guided project that is framed within the context of a real civil engineering problem and based on real data sets. As skills are developed, tasks become less guided, promoting students to think independently about how to utilize the software to accomplish specified outcomes without being told the exact process. This higher level of learning is applied directly in completion of tasks for the infrastructure project. Ultimately, this course seeks to simultaneously teach both civil engineering concepts and software skills through interactive and project-based learning, providing a pedagogical framework that can be applied in other courses using discipline-specific software.

Introduction and background

As professors we seek to prepare students to play a vital role in improving quality of life of people while protecting the environment through civil infrastructure projects. Although it is impossible to predict how the classroom and workplace environments will evolve, it is important that the engineering community engage in discussions relevant to teaching to facilitate engineering design in an accelerating world. Here we describe a course that creates a platform for using software as an innovative teaching strategy to facilitate active learning and collaborative innovation, highlighting real-world connectivity between the classroom, workplace, laboratory, and the infrastructure systems that engineers seek to analyze and design. This course addresses challenges in linking the classroom and real-world application by engaging with students through innovative teaching activities that foster understanding, application, and creativity while also providing a safe environment for mistakes and open discussion.

This course leverages projects for transfer of knowledge. Previous studies have shown the benefits of project-based courses to CEE education; helping to illuminate principles, aid students in linking concepts to the real world, and even aiding in student retention [1], [2]. For this course, a core project is facilitated through GIS. Since the 1990s GIS has been widely recognized as a beneficial tool to the engineering profession [3]. The tools presented in GIS software cross multiple disciplines making it an ideal platform for exposing students to a range of aspects within civil engineering projects. GIS can be used to solve complex spatial problems and design infrastructure systems, but its application requires integrated perspectives that are traditionally lacking in civil engineering curricula [4].

Learning the setup and tools available in the software is crucial for students to understand how GIS works. However, if instruction is too heavily focused on the technical skills of using GIS, then the theory, concepts, or science behind the problems being explored may not be fully understood [5]. In an engineering context, GIS has tremendous potential as a teaching tool to improve student learning of various civil engineering concepts, whether through simulations, data exploration or manipulation, or example projects from different civil engineering disciplines. For instance, flyover animations of a topographic surface in a GIS map can help students connect the two-dimensional representation of elevation data to its three-dimensional reality, thus improving visualization skills. Working with large spatial datasets such as documented vehicular crashes in Philadelphia allows students to connect numerical data to its geospatial component, looking not just as how many crashes occurred, but instead assessing why and where did they occur and how can they be prevented. When students make connections between concepts, it is invaluable to their learning. Past efforts to teach GIS in an engineering technology curriculum have shown that course content should be tailored to the specific audience using relevant applications, and that group work should be promoted so that students can learn from one another [6]. GIS is the ideal platform for connecting concepts and data to their engineering applications through collaboration. As new tools and software become increasingly available, it is crucial for teachers to adapt in how they can utilize technology to enhance student learning.

This course covers basic principles of GIS and their use in spatial analysis and information management. Through use of a core project that thematically ties this course together, students develop a knowledge base and technical skillset in valuable engineering skills such as project layout, data management and sharing, spatial analysis, and graphical communication for reports and visualizations. Additionally, students learn basic programming skills in Python, complementing their GIS skillset with computational analyses that can enhance workflow and efficiency. The nature of the course encourages self-learning and independence. This GIS course may serve as a model for future software-based courses within civil and environmental engineering, potentially providing a framework that can be adjusted for other courses geared towards application in other discipline-specific software.

Course overview and objectives

GIS for Civil Engineers is an upper-level elective course in Villanova's Department of Civil and Environmental Engineering (CEE) that satisfies a CEE software elective within the program's curriculum. This 3-credit course meets once a week for 165 minutes, essentially scheduled as a

lab period. Students come into the course with a very basic understanding of GIS from their initial exposure to the software in a required freshmen-level course, Civil Engineering Fundamentals [7]. Currently in its first offering, this applications-based civil engineering course was designed for students to build upon that basic GIS knowledge in a way that pushes them beyond simply learning how to use a specific software. Rather, the course utilizes the most recent version of ArcGIS Pro and its powerful technology to improve student learning and understanding of basic civil, transportation, environmental, and water resources concepts, while also improving student skills in data visualization and analysis.

The course objectives are as follows:
1. Understand GIS setup, terminology, and applications.
2. Relate the phases of project planning and design and how spatial data informs each phase.
3. Organize large geospatial datasets using data management techniques.
4. Apply GIS tools and techniques to analyze spatial datasets relevant to civil engineering.
5. Present technical information, data, or analysis results clearly in map, web, or graphical format.
6. Evaluate components of sustainability in each phase of a civil engineering project.
7. Begin to develop self-learning and exploration skills in a computer program.

These overall objectives are pursued using a structure that first establishes a working knowledge of ArcGIS Pro, then a sequence of projects that imitates the civil engineering planning and design process as fundamental concepts are reinforced. A two-part Core Project ties the course together as student groups work through a residential site development project from planning through construction.

Course and core project details

There are three primary sections to the course, all of which ultimately map back to the Core Project. The below discussion first provides background on the Core Project. Then, each of the course sections is described in detail in terms of the course objectives that are addressed, number of classes dedicated to that section, software and civil engineering-related concepts that are taught and/or reinforced, and how the Core Project is integrated throughout.

Core project description
The two-part Core Project represents the key application of the civil engineering concepts and GIS software skills being obtained in the course. The final deliverables of the project are an oral presentation and digital story map at the conclusion of each part. Part 1 of the project requires students to complete due diligence on an existing, undeveloped tract of land, then based on those findings, propose a conceptual layout for a residential subdivision that adheres to local zoning regulations and other design criteria. For Part 2 of the Core Project, students are provided with the proposed design for that project. They are then required to perform an extensive analysis of the design, including quantifying proposed land cover changes, delineating sub-basin drainage areas to each stormwater inlet, calculating earthwork volumes, developing roadway profiles, compiling material quantity estimates for construction and cost estimation, and creating a database for asset management of built features. Using a real project design for Part 2 instead of

building on the conceptual layouts created by students in Part 1, ensures that in-depth analyses can be performed. For example, for many of the analyses mentioned above, detailed grading for the site design is required. Having students complete detailed grading for their site design is a higher-level concept, beyond the scope of this course. A real design also allows the instructor to use that design as an additional teaching tool.

Collectively, the Core Project follows the sequence of the project planning and design process, and as such, it is a comprehensive learning activity that addresses each course objective. Completion of the project requires not only a solid grasp on how to use ArcGIS Pro, but also a strong understanding of the many civil engineering concepts that are related to a site development project. As currently structured, four class meetings throughout the semester are dedicated solely to the Core Project. Two classes are project working sessions where student teams can collaborate with each other and ask the instructor questions during class time, while student presentations for each part of the project use an additional two class meetings.

For this first iteration with a small enrollment of 14 students, there are two groups of five and one group of four. Students chose their own group, work with the same group throughout the semester, and complete peer evaluations after each project submittal. In future offerings, the goal is still to restrict group size to four or five based on workload, but if enrollment increases, more groups will need to be accommodated. While larger classes would present some challenges for instruction in such a course, the Core Project model is scalable to larger classes sizes. Currently, each group is working on a shared single project site. With higher enrollment, multiple project sites could be incorporated to facilitate more diverse final projects. Given the versatility of site development projects, this is a feasible approach but may be limited by data availability.

Section 1. Fundamentals and basic tools
In the first section of the course, students learn about the setup and interface of ArcGIS Pro, as well as concepts that are foundational to GIS analysis such as coordinate systems, geodatabases, data types, table storage, data attributes, and mapping. Students apply these basic concepts by working with transportation and structural data sets (e.g., vehicular crash data in Philadelphia, bridge inspection data) but the focus is more about how to use the program and not on the technical details of the data within those disciplines. Basic mapping skills are learned in various formats, including static map layouts, web maps, and development of web applications. The Core Project is introduced, but no specific tasks related to that project are completed in this initial section of the course.

Objectives: 1, 3, 4, 5, 7

Number of classes: 3

GIS concepts: Base knowledge related to coordinate systems, data types, and data attributes; tools to efficiently search, summarize, combine, or filter spatial data; mapping (static maps, web maps, web applications)

Civil engineering concepts: minimal

Example project: Mapping locations of structurally deficient bridges over impaired waterways

Section 2. Project planning and site assessment
In the second section of the course, students apply GIS to analyze data sets within the context of project planning. The importance of site assessment for planning purposes is stressed. Students

access data sets commonly used by civil engineers such as digital elevation models (DEMs) that represent topographic surfaces, land use, soil types, flow lines, and wetlands. Based on their findings, students perform zoning calculations to determine what the required open space area for conservation would be if developing on an undeveloped property, in addition to how much of the property can be built on subject to other site-specific constraints. Completing this process first for an example location, students are able to apply what they learn to aid in developing a conceptual site plan layout for the Core Project. Thus, students use spatial data analysis of the existing site conditions to inform their decision making process for the subdivision layout. Various feature editing tools are introduced in this section of the course, which students apply for creating layout elements (e.g., roadway, right-of-way, lots, setbacks). Basic applications of programming in Python and tool automation in Model Builder are also introduced in this section of the course, the latter of which is used for the Core Project in Section 3. Students are not required to have any prerequisite programming knowledge, which has resulted in a more conceptual approach to understanding code structure, loops, and automation as opposed to having students write a Python script from scratch.

Objectives: 2, 4, 5, 6, 7

Number of classes: 3

GIS concepts: Raster data sets; spatial analysis tools; creating and modifying features; workflows and tool automation

Civil engineering concepts: Elevation surfaces; slopes; land use; riparian buffers; zoning calculations; open space; subdivisions; site layouts; setbacks

Example project: Site assessment and zoning calculations for undeveloped tract of land

Section 3. Design analysis and construction
The third section of the course focuses on analyzing elements of a proposed design through calculations and graphical output, as well as performing various construction-based calculations and managing as-built infrastructure data. Utilizing several example projects, students learn how to apply GIS tools to more efficiently perform tasks that are much more time-consuming or even subjective with other methods such as watershed delineation or cut/fill calculations. Students apply these tools to the proposed design in Part 2 of the Core Project. This portion of the class also presents opportunities to teach students 3D visualization capabilities of the software, which they can apply to improve presentation of spatial data or project designs. Finally, students learn the basis of using GIS for asset management, developing a database for stormwater control measures on campus and again applying that same approach to the proposed design in the Core Project.

Objectives: 2, 3, 4, 5, 6, 7

Number of classes: 5

GIS concepts: TIN creation; breaklines; 3D visualization, scenes; animation; and feature extrusion; creating graphs from surfaces; tool automation

Civil engineering concepts: Watersheds and runoff; profiles and cross-sections; earthwork (cut/fill); cost estimation; material quantities; infrastructure asset management

Example project: Cut/fill calculations using existing conditions and proposed design surfaces

Integration of projects

In addition to the Core Project, fundamental civil engineering concepts are integrated into the course through a collection of realistic projects that students complete individually using ArcGIS Pro and real datasets. Project data is a combination of open source data, shared content from the ArcGIS Online user community, and industry contacts. This approach provides students with a wide array of spatial data sets to analyze and work with and exposes them to various data sources that exist. These projects are formal assignments that students typically start in class then finish as homework. This allows students to work at their own pace, while getting assistance from the instructor as needed. There is some collaboration during class, but these are primarily individual assignments. While project work for a software-based course is not novel itself, the integration of these different projects contributes to a course structure in which students learn software skills while also learning how those skills can be applied to real engineering problems. Each project is presented with a problem statement, framed such that the student is the engineer who must apply GIS skills and analyses to solve the problem for specified stakeholders. The individual projects were developed in a way that emphasizes connections of topics within the broader context of a single civil engineering project, especially how certain design or analysis tasks build on previously completed analyses. Students are first introduced to one element of a project, then later revisit that same project in search of a new outcome as they have further developed their GIS skills. Two examples of these integrated projects are discussed below. Descriptions include an overview of the project site, the problem(s) students are tasked with solving, the subdiscipline within civil engineering that is highlighted, the number of individual student submittals required, and the course section within which each submittal is covered.

Example 1: Contaminated Gas Station
The project site is a gas station where soil and groundwater contamination possibly may have occurred due to leakage on site. For the first submittal, a monitoring well location plan is provided and must be used to determine the exact well locations. Because the plan is in PDF format, students must first georeference the well location plan in the proper coordinate system in GIS, then create point features at each well location in order to calculate their coordinates. Also, as part of the first submittal students are required to do some research on the maximum contaminant level (MCL) of benzene and toluene as well as the possible side effects of each when humans are exposed. For the second submittal based on this project, students revisit the gas station site but are now provided concentration data for the various contaminants from the monitoring wells. They are then required to input that data into the feature attributes at each well location, which is subsequently used to develop surfaces and contour lines reflective of the groundwater table elevations and benzene and toluene concentrations across the site (Figure 1). Students interpret the surface and contour results to determine the direction of groundwater flow and compare the pollutant concentrations on-site to EPA permissible levels for drinking water. Based on their interpretations of these spatial results, students must assess the overall impacts of the project by determining whether the residential development adjacent to the site (which relies on groundwater for their drinking water supply) is likely to be adversely affected by this leakage.

Subdiscipline(s): environmental

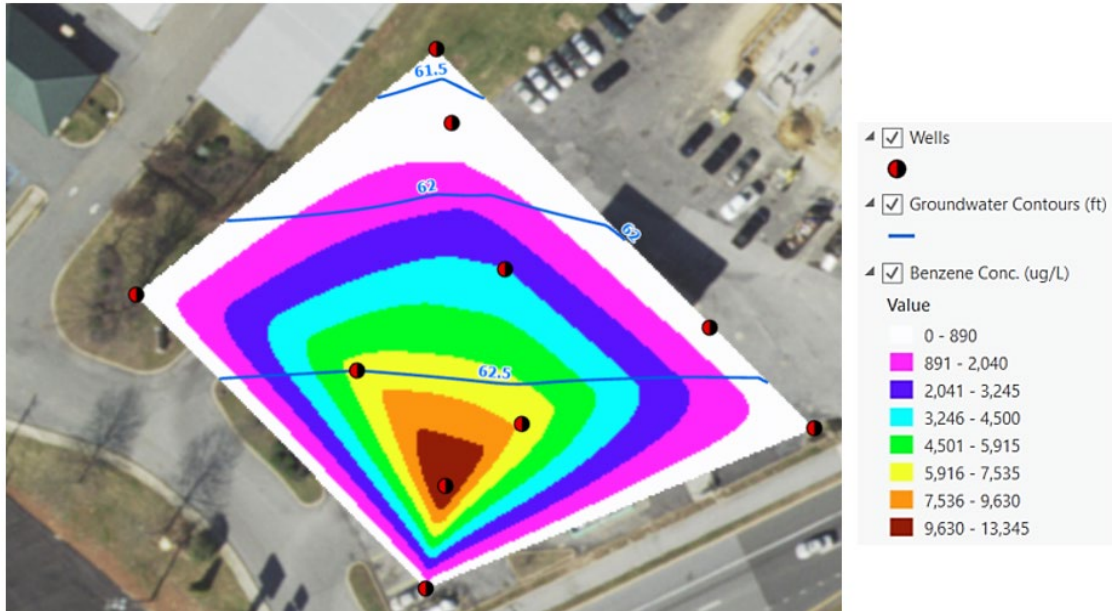Individual submittals: 2 (Section 1; Section 3)

Figure 1. Sample output from example project 1 (contaminated gas station). Spatial benzene concentrations are shown with

Example 2: Undeveloped Property in PA
The project site is an undeveloped tract of land in Pennsylvania. The first submittal based on this project is a key exercise in Section 2 of the course, with focus on project planning and site assessment. Students access spatial data sets of elevation, land cover, soil type, and surface water features, then quantitatively summarize the existing conditions of the undeveloped property (e.g., mean and maximum slopes, soil types and areas, % coverage of property for land use and soils). Based on these findings and local ordinances, students then perform zoning calculations to determine the minimum required open space and how much of the property can be developed. The problem is framed within the context of performing due diligence for future development, essentially providing a blueprint for certain tasks in Part 1 of the Core Project. For the second submittal with this project, students are required to calculate the peak runoff from this site to serve as the basis for meeting stormwater management regulations once the property is developed. To complete this second submittal, students need to delineate the watershed draining the property using a sequence of hydrology tools in ArcGIS Pro, then apply what they learned in the first submittal to determine inputs for a regional regression calculation of peak flow rate (specifically mean elevation and percent urban area). To assess overall importance of stormwater management, students are required to perform some light research into green stormwater infrastructure (GSI) and its impact on sustainable development.

Subdiscipline(s): water resources

Individual submittals: 2 (Section 2; Section 3)

Instructional framework

The instructional model for this course aligns with an adapted version of Esri's five levels of instructional use of GIS [8] applied within the project-based nature of civil engineering where both software skills and core civil engineering concepts are being taught. In this model, levels

progressively build up in complexity and guidance provided to the students, starting with Level 1 in which presentations and demonstrations are used to deliver basic content. Level 2 utilizes scripted activities, where outcomes are linearly achieved by following a very specific set of instructions. In Level 3, the expanded script level, students need to apply similar skills or tools learned through a scripted project to a slightly different application or problem. Level 4 uses the idea of directed projects, which provide students with some data and defined outcomes, but requires them to determine the best course of action to obtain the outcomes. Finally, the most complex application of GIS within a course is a custom project (Level 5) where students independently develop and complete a project of their choosing with minimal to no guidance from an instructor. Outcomes in the five level model can be approximately mapped to the revised Bloom's Taxonomy [9], with the highest level of learning attainable (Creating) through the custom projects in Level 5 (Table 1). Scripted and expanded script projects (Levels 2 and 3, respectively), are mostly closely targeted at the Applying level of Bloom's Taxonomy, where tasks are executed based on prior knowledge and skills.

Table 1. Application of 5 levels of instructional use of GIS with highest level learning targets based on revised Bloom's taxonomy.

Level	Description	Overview of Application in GIS Course	Highest level learning targets
1	Presentations & demonstrations + in-class activities	Integrated into delivery of primary course content. Some are instructor led; others are student-driven. Students are given credit for completing in-class activities, but not graded on correctness. Used as part of 11-12 classes.	Understanding
2	Scripted projects	Integrated projects where students are provided a detailed tutorial and data set to solve a real civil engineering problem. 5-6 individual submittals.	Applying
3	Expanded script projects	Later submittals for some integrated projects, where previous projects are built upon (1-2 individual submittals). Some elements of Core Project (both parts).	Applying
4	Directed projects	Some elements of Core Project (both parts).	Analyzing
5	Custom projects	Not currently used	Creating

Levels 1 through 4 are utilized throughout our course (Table 1), with interactive demonstrations interspersed within the traditional delivery of course content. The instructor provides demonstration data sets to the students, then leads them through a short activity based on that data set to show the software tool or feature being highlighted in that particular class. Several other in-class activities are utilized more in a Level 1 capacity than Level 2, where detailed instructions are provided but the tasks are completed as a group. These are ungraded, "low-stakes" activities where students can learn how to use the program to answer a set of questions without fear of losing points. Scripted projects (Level 2) mostly comprise the integrated projects described above wherein students practice the software skills for solving a civil engineering

problem. These scripted projects are written with detailed instructions that students can work through at their own pace. Some elements of the Core Project are essentially expanded script projects (Level 3), requiring an analysis from a scripted project be applied to a new data set (i.e., the Core Project site). Other elements of the Core Project are considered to be directed projects (Level 4); students are given project requirements, guidelines, and initial data sets, but are not specifically told how to do certain tasks, therefore requiring analysis of possible approaches. The reasoning behind not making the Core Project a full Level 4 project is that students are still developing their understanding of the software at this point. If the project requirements are too great in terms of software tasks, there is a risk of them losing grasp of the civil engineering outcomes. Level 5 projects are not currently incorporated into this course due to the dual focus between software skills and civil engineering topics. However, there may be the potential to add optional projects that fall into this category to encourage highly motivated students to pursue more advanced GIS work.

Student feedback

Preliminary student feedback on the course structure suggests positive results. After the first five weeks of the course, 12 of the 14 students in the class provided anonymous feedback regarding how various learning activities being used in the class are contributing to their learning (Table 2). Students were asked to "Please rate the following class activities on how effectively each contributes to your learning in this course" with a score of 1 indicating "Not helpful at all" and a score of 5 indicating "Extremely helpful."

This initial student feedback suggests that utilizing diverse classroom activities for content delivery and hands-on practice in the software is generally effective for contributing to their learning. The scripted projects have been especially well-received, with students appreciating the level of guidance provided in such activities. In fact, when asked whether they would prefer more opportunities for unscripted projects, 75% disagreed while 25% had no strong preference. As students are still developing a comfort level with the software and GIS at this point in the semester, this is not an unexpected response. Future feedback will be collected to determine if these perceptions shift after completion of the course.

Table 2. Summary of survey questions and results collected after five weeks of course.

Learning Activity	Average Scores (max score of 5)	% Responded with 4 or 5
Lectures/notes	3.8	75%
In-class demonstrations	4.4	75%
In-class activities (non-graded)	3.8	50%
Scripted projects (graded assignments with step-by-step instructions)	4.8	92%

The lower scores for lectures should be somewhat expected in an applications-based course, but these scores are also likely lower in part due to the lecture content being skewed earlier in the

semester as terminology, setup, and basic GIS tools are being discussed. Lectures in this course comprise the first 30 to 80 minutes of a given class meeting, depending on content, and serve as a means to introduce the broader concepts being explored in that class. The lectures primarily consist of background information, definitions, GIS tool setup, and example CEE applications, with some demonstrations typically also included. The course is structured so that more class time is dedicated to hands-on applications and projects as the semester progresses and topics become more advanced. Therefore, we expect that as overview lectures become shorter and more focused on that day's topic or project, students will recognize the importance of those details.

Finally, the ungraded in-class activities received the lowest scores. While we believe there is still much potential for those types of learning activities, the implementation of those exercises will need to be improved. As most students prefer guided instructions that form the basis of the scripted projects mentioned above, an inherent obstacle with using ungraded, in-class activities in a software-based course is students' preference to work at their own pace, rather than following along together to answer questions as a group. Additionally, these types of activities need adequate time, so they are not rushed during class. This facet of the course requires refinement but will continue to be used as a way to reinforce tools and concepts without the pressure of submitted work to be graded.

Student learning and their perceptions of how the course structure contributes to that learning will continue to be assessed for this new course. Early feedback has been positive, but there are higher level course elements that still need to be explored through future assessments. For example, the effectiveness of the Core Project and the role of the entire course in teaching concepts and skills in GIS, graphical communication, and civil engineering concepts are questions that will be asked to assess whether course objectives are being met. There are exciting opportunities to refine this course moving forward as we receive more student feedback.

Adapting course framework

The integration of projects and core civil engineering concepts throughout this class contributes to a general course structure that we feel can be adapted for implementation in other civil engineering courses where a discipline-specific software is utilized. Thus, we are proposing that our GIS course can serve as a foundational framework for teaching both software skills and civil engineering concepts in a software course, while also addressing broader technical objectives such as data analysis, visualization, and graphical communication in a given software package.

To adapt this course structure in a meaningful way with different software, we recommend that several key aspects of this instructional framework be maintained, regardless of software:

1. *Core project*: Using a core project gives students a vision for how the tools and skills they are learning in a software are applied to achieve an overall goal. A core project connects all the discipline-specific topics together with how software tools are used to explore those different topics. Given its interdisciplinary nature and clear sequencing of project phases, a site development project is ideal for a software-based course, especially a GIS or CAD-based course. Depending on the software being implemented and the course discipline, other project types could potentially be used if comprehensive enough in scope.

2. *Project integration*: Using smaller projects throughout the course that build on themselves can help students recognize connections between key civil engineering concepts and project phases. Additionally, framing projects in a context that places them in the role of engineer rather than student should promote a broader perspective that goes beyond simply following steps to complete a task in a computer program. This is an approach that can easily be integrated into other software-based courses, regardless of the software being used. Too often in our experience with teaching both GIS and CAD, students tend to get lost in the software instructions, forgetting the overall objective. Thus, the key with this approach is to stress the application of what students are trying to accomplish within their respective discipline, assigning tangible meaning to each step completed in the program. We feel that can potentially be even more impactful by revisiting different aspects of the same project at various points within a course.

3. *Instructional hierarchy*: With the adapted five level instructional hierarchy presented above as a guide, a software-based course can utilize a range of demonstrations, ungraded interactive activities, scripted projects, and expanded script/directed projects in order to promote software skills and reinforcement of discipline specific concepts. This approach should have merit in any software, as students can continue to develop through these successive levels of instruction from obtaining basic knowledge to applying critical thinking in an unguided environment. Working from a level-based structure should also help students deconstruct more advanced projects into their component parts, contributing to more manageable tasks and an emphasis on discipline-specific concepts. Finally, including a Core Project as a central element of a software-based course allows the different levels of instruction to be easily incorporated. Some projects that provide guidance for future Core Project tasks can be worked into the course, in addition to others that are less defined and only applicable to the actual Core Project.

4. *Promotion of self-learning*: The ability to teach oneself how to use a software program is invaluable for students as they develop into practicing civil engineers. Fostering this ability is a crucial element to a software-based course, and it can take on several different forms depending on the software. Within the instructional framework presented, Level 4 or Level 5 projects would directly promote students to develop self-learning skills. For a GIS-based course, the ArcGIS Pro help documentation is extremely thorough, but also attainable for beginners. Students should be encouraged to utilize this documentation whenever necessary. Additionally, there are numerous lessons (tutorials) available online for students to pursue on their own time or as part of a course requirement. Our course currently requires students to complete two of these lessons during the semester, presenting the results of the first lesson to the class. With this structure, students gain practice in presenting technical information in map or web-based format but are also exposed to the wide-ranging applications of the software. While ArcGIS Pro has the supporting online resources for such an activity, a similar approach could also be employed using specific tools within other software.

Conclusions

A new course in GIS for civil engineers has been successfully developed and is currently in its first offering. This course was created with a dual-purpose; to teach concepts and skills in GIS in addition to teaching core civil engineering concepts through application. The course is composed of three sections. After the first section covers fundamental GIS concepts and software-specific tools, the second and third course sections mimic the civil engineering design process from project planning through construction using a Core Project to tie these different phases together. Smaller, integrated engineering projects are used throughout the course to teach not only civil engineering applications through a common software, but to reinforce civil engineering concepts, highlight the interconnectedness of the different project phases and provide the skills necessary to complete the Core Project. A tiered instructional framework is being implemented in which students are introduced to concepts through presentations and interactive demonstrations, then apply those concepts by following scripted projects, as well as higher levels of applied learning through expanded applications where not every task is scripted, but independent learning is facilitated. Through the development of this course, we aim to provide a framework that can be adapted with other discipline-specific software, either in civil engineering or other engineering fields. Preliminary student feedback has been encouraging, particularly in regard to the level of guidance provided by scripted projects, but we recognize the need for more student assessments as the course continues to evolve.

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