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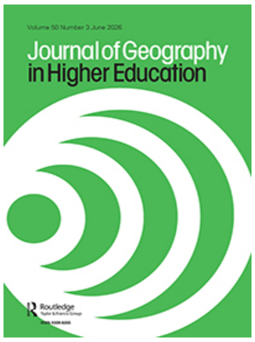

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The Guide to the *Geographic Approach*: a modern curriculum for GIScience

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ABSTRACT
In the 1990s, a core curriculum for GIScience was developed to provide a lighthouse for the field. Given massive developments in the field, our goal is to lead the GIScience community in creating a modern and open-source curriculum for today's GIScientist, through a project titled "The Guide to the Geographic Approach." Here, we outline resources generated from the first phase of the project. It includes a list of modern Geographic Information Science (GIS) competencies, open modules organized around GIS workflows and applications, and supporting instructor materials. The approach to modern GIScience curriculum development and delivery is motivated by a shared understanding that materials should be co-developed by the community of GIScientists, be open source, center ethics, be distinguishable from data science through learning focused on spatial applications and workflows and build practical skills through hands-on activities using the latest technology. With the aim of providing content that addresses a set of modern GIScience competencies, we introduce the first phase of curriculum materials. Using an example module, we describe curricular components of each module and outline how materials can be used, as a complete curriculum or in their component parts.

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Introduction

GIScience has advanced rapidly in the past three decades (Frazier et al., 2018, 2025). Since its establishment, the field of GIScience has become a mainstay for organizations conducting research, managing assets, supporting decisions, and monitoring change. Beyond the proven utility of GIS, technology advancements have made GIScience mainstream as widespread use of the internet and proliferation of the Global Positioning System (GPS) created opportunities for collecting and analysing data (Goodchild, 2009). Recent technology developments, such as artificial intelligence (AI), are supercharging GIScience, as it is increasingly possible to quickly extract spatial patterns and information from massive amounts of diverse geographic data and imagery. Changes in geographic data and processing capabilities continue to unlock exciting new directions and applications for GIScience (Hochmair et al., 2025; Huang, 2025).

The success and ongoing evolution of GIScience also create challenges for both scholars and practitioners. For example, the ongoing emergence of data science as a field that, in part, leverages the explosion of big spatial data to address applied problems, can make it difficult to distinguish data science that uses geographic data from GIScience (Lee & Kang, 2015; Zou et al., 2024). However, GIScience is distinct from data science in that it centers on the development of core geographic concepts, such as spatial autocorrelation, edge effects, and the modifiable areal unit problem (Oliveira et al., 2024), and the deployment of those concepts to advance scientific discovery. Additionally, GIScience, born from geography, provides a unique approach to asking and answering questions through systems thinking and the lens of location (Goodchild, 1992).

A key way to continue to distinguish GIScience as a unique and impactful field is through curriculum. GIScience curriculum is grounded in spatial thinking which makes sense of problems that bring together

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skills for thinking about relationships between both spatial and non-spatial entities as well as spatial approaches to problem solving (2005; Hegarty, 2011; Uttal & Cohen, 2012). The GIScience core curriculum, developed initially through the National Center for Geographic Information and Analysis (NCGIA) in the 1990s, has served the field well. A shared curriculum enabled the GIScience community to have a common understanding of foundational concepts and consistent language (Goodchild & Kemp, 1992). Following over three decades of ongoing development and change, revisiting the GIScience curriculum offers an opportunity to reinforce core concepts and integrate new concepts, reimagine GIScience skills, and enhance the lighthouse created by the initial core curriculum with newer pedagogical approaches. Building on the shoulders of GIScience scholarship on education (e.g. Unwin et al 2011), we revisit how curriculum can support instructors, students, researchers, and practitioners as they work to solve the world's problems and educate the next generation of GIScientists (DiBiase et al., 2006; Frazier et al., 2025).

In this paper, we present the *Guide to the Geographic Approach*, a community effort to update and revise the GIScience curriculum in light of the significant technological and real-world changes of the past 30 years. Initiated as a partnership between UCSB's Center for Spatial Studies and Data Science and Esri, the industry leader in GIS software, the intention of this project is to facilitate a conversation about modern core competencies in GIScience and to build a platform for delivering and sharing open-source teaching materials that instructors can adopt in their own courses. Here, we outline a set of principles guiding the development of a modern curriculum, introduce competencies that have emerged as essential for a modern GIScience curriculum, outline how the open-source teaching materials and associated guides can be adopted by instructors, and highlight next steps for growing this project. The initial materials of the *Guide to the Geographic Approach* are aimed at undergraduate level education in GIScience, however they also can be adapted for advanced secondary school audiences or introductory graduate level courses. Additionally, the competencies and ethics lessons are applicable to curriculum at any level.

Guiding principles for the *Guide to the Geographic Approach*

Several principles have guided our team in the development of the *Guide to the Geographic Approach* (Figure 1). These include core competencies or a shared understanding of what should be learned, open-source materials that can be broadly used, inclusion of lessons on ethics, a focus on solving critical problems, and the integration of modern technology.

The first principle is that a modern curriculum for GIScience should be built around competencies and themes that are meaningful to the community of GIScientists (Ahearn et al., 2013; DiBiase et al., 2006; Wilson, 2017). Although the Guide to the Geographic Approach was initiated as a partnership between UCSB and Esri, from the outset, our intention was to facilitate a community-wide conversation about evolving teaching and curriculum needs. Initial engagement of the community has been facilitated through

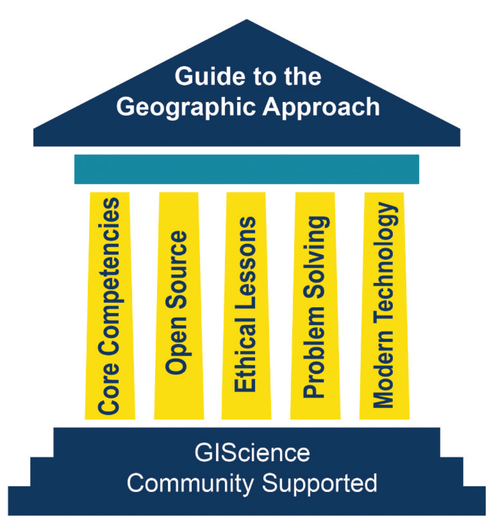

Figure 1. A visualization of principles that guide the *Guide to the Geographic Approach*.

workshops and outreach events at conferences, including the Association of American Geographers (AAG), the University Consortium of Geographic Information Science (UCGIS), and the Esri Education Summit. A series of webinars was also held to reach a wider audience. During these sessions, experts were asked to brainstorm and prioritize competencies, skills, and applications that are essential to a modern GIScience curriculum. We intend to continue holding these sessions at disciplinary events. We also established an advisory board for the project that includes GIScience experts from around the world and across a range of institutions. We aimed to achieve diverse participation on the advisory board by including representatives from North America, Asia, and Europe, from teaching focused and research-intensive institutions, and from industry, academia, government, and non-profit organizations.

The second guiding principle of the *Guide to the Geographic Approach* is that all materials generated from this work should be openly available and open source so that learners can not only access them freely but instructors can adapt them accordingly to fit their specific course needs. Developed with input from the community, the materials produced by the project are for the shared benefit and betterment of the field. All aspects of the work are open and fully adaptable, from the learning videos to the storymaps, to the competencies and question banks. However, perhaps the most useful are the teaching materials that can be freely adopted. These materials and options for how to use them are discussed in detail in the Open Teaching Materials section of the manuscript.

The third guiding principle is that ethics should be central to all curriculum and learning. The field of GIScience has been critiqued for its limited inclusion of ethics, at best tacking it onto the end of a course (Elwood & Wilson, 2017). Given the power of geographic data and maps to influence perceptions and decisions, modern GIScience curriculum should be leading all data science in the integration of ethics training (Fernholz et al., 2025; Frazier et al., 2025; Nelson et al., 2022). As such, every workflow, presented as a module, includes an ethical lesson and activity. Building on the GIS Professional Ethics Project (DiBiase et al., 2012), the *Guide to the Geographic Approach* includes ethical lessons and case studies for each learning module constructed around a robust ethical framework, discussed below.

The fourth guiding principle is that modern GIScience should focus on solving problems. Algorithms and methods are critical to effective GIScience, but one of the important aspects for differentiating GIScience from data science, more broadly, is the ability to link algorithms to applications in order to ask spatial questions and provide solutions for improved decision making (Longley et al., 2015; Miller & Goodchild, 2014). In the *Guide to the Geographic Approach*, curriculum is presented as workflows for answering application specific questions. For example, a workflow might be presented on how to identify disease clusters to stop spread or make decisions about where to put new protected areas based on a site suitability analysis. By putting the workflow up front, the *Guide to the Geographic Approach* flips the more traditional model of presenting specific skills that build up to workflows.

The fifth guiding principle is that a modern curriculum should include modern technology, specifically web-based GIS applications, and leverage the newest technologies, including AI (Hochmair et al., 2025; Kerski, 2015). The applications, workflows, and theory associated with GIScience curriculum are software agnostic. With Esri's partnership, the initial set of materials has been created using open portions of the ArcGIS software suite to help instructors make the transition to an online platform that is automatically updated and does not require students to install software. However, we understand the value of producing materials that leverage multiple platforms and coding environments, and as the project grows, contributions that leverage other tools are encouraged.

Competencies

A key, continuously evolving outcome of this work is curation of a list of competencies that set the conceptual and technical foundations of work in GIS-related fields. Most of the competency areas on this list are not new. Rather the list builds on the prior work of the core curriculum of the NCGIA (National Center for Geographic Information and Analysis, 1990), the GIS&T Body of Knowledge (DiBiase et al., 2007, 2010), the U.S. Department of Labor Geospatial Technology Competency Model (U.S. Department of Labor Employment and Training Administration, 2025) and the GIS Certificate Institute (GISCI) Geospatial Core Technical Knowledge Exam (GISCI, 2024). What is new is a series of competencies related to AI and machine learning. As well,

Table 1. Fifteen competencies of a modern GIScience curriculum.

Competencies Areas	Description
Geodesy and Coordinate Systems	Covers the principles and techniques used to represent the Earth's shape and location systems accurately, including datums, projections, and coordinate systems.
Data Quality and Metadata	Focuses on the evaluation of spatial data integrity, accuracy, precision, and proper metadata documentation to ensure reliable GIS outputs.
GNSS and Positioning	Deals with the use of satellite navigation systems and related technologies to determine precise geographic positions.
Remote Sensing and Image Analysis	Includes sensor platforms, image processing, classification, and analysis techniques for interpreting remotely-sensed data.
Cartography and Visualization	Encompasses principles of effective map design, symbolization, thematic representation, and visualization using dynamic media.
GIS Analysis and Spatial Modeling	Covers spatial relationships, analytical methods, spatial models, and procedures for addressing complex geospatial problems.
Data Acquisition and Integration	Includes collecting, digitizing, georeferencing, and integrating diverse geospatial datasets to build comprehensive GIS databases.
Spatial Databases and Data Modeling	Focuses on spatial and non-spatial data modeling, database design, and query methods essential to effective GIS applications.
Programming and Automation	Utilizes scripting, APIs, and software tools to automate geospatial workflows and customize GIS applications.
IT Systems and Cloud Integration	Explores geospatial IT architecture, cloud computing, and system performance optimization for modern GIS environments.
Ethics, Privacy, and Legal Issues	Addresses professional ethics, legal considerations, data privacy, and responsible data sharing in geospatial contexts.
Cadastral and Land Records	Involves mapping and interpreting property boundaries and legal descriptions using cadastral principles.
User-Centered Design and Communication	Emphasizes stakeholder engagement, user interface design, and communicating geospatial insights effectively.
AI and Machine Learning in GIS	Applies AI and machine learning methods to spatial analysis, classification, and automation within geospatial workflows.
Emerging Technologies and Trends	Explores new tools and trends such as UAVs, big data, cloud GIS, and LLM integration in geospatial practice.

emerging technologies and trends, including Unmanned Aerial Vehicles (UAVs), big data, cloud GIS, and large language models (LLMs) are addressed. See Table 1 for a list of competencies, which is still evolving through feedback from experts and cross validation with multiple research projects on GIScience curriculum.

Given the rapid pace of technological change and ongoing shifts in the social and physical environment, keeping this list of competencies in tune with the real world will require continuous monitoring and updating. This initial set of competency areas was generated through a review of the curricular and competency materials identified above, the open solicitation of suggestions and feedback at conference workshops, and in consultation with a panel of international GIScience experts and collaborators. Moreover, several of these topics merit more in-depth examination. For example, a consensus has yet to emerge as to how AI tools can or should be integrated in GIS workflows, and it remains unclear which AI related skills should be taught in GIScience courses. An opportunity currently exists for GIScience educators to contribute to this vital conversation and drive future practice toward an ethical, reliable, and sustainable future.

Open teaching materials

The primary output of *The Guide to the Geographic Approach* is a series of learning modules that have been developed by GIScience faculty, graduate students, and in partnership with the Esri Education and Tutorials teams. Each module includes GIS foundations, ethical lessons and case studies, hands-on technical skills, and a problem-based lab that can be adopted as a full lesson or broken into the component parts and used by instructors as needed. Each module is centered on a specific application or problem that requires spatial thinking and a GIS workflow. Modules are packaged using ArcGIS StoryMaps and each module is intended as a unit similar to one week of content in a typical semester of an undergraduate course.

Modules begin with a problem or application-oriented question, typically conveyed through a story. For example, in the "Analyze health-care access during extreme weather events" module, students quantify differences in access to pharmacies in normal conditions and during an extreme flooding event.

Modules then identify a GIS workflow needed to address the applied questions. In the health-care access module, the workflow maps spatial access and change. As such, the primary workflow in this module is measuring spatial accessibility and evaluating how different environmental conditions change measures and maps of accessibility. The theory is taught with diverse materials including a combination of videos, figures, and writing.

The technical skills needed to operationalize the workflows are taught through videos and hands-on instruction. In the health-care module, students learn to define a catchment area using methods for a Two-Step Floating Catchment Area. Nested within the methods are lessons on how to gather and visualize spatial data, explore data, define a study area, determine network distance by drive time, and design a workflow.

Every module also includes ethical lessons. In the health care access module, the ethical lesson is about how planning, especially for disasters, can overlook planning for the needs of people who face systematic bias. For example, students are asked to consider how disaster planning could support disabled persons with limited mobility or provide safe storage for temperature sensitive medicines for unhoused people. Ethical lessons are provided as videos and supported by thought case study exercises.

Following the theoretical and practical lessons, a problem-based lab is provided. Problem based labs provide students with an opportunity to apply all the knowledge they have learned to a unique data set and also often include ideas about how they would do this with their own data.

The first phase of The Guide covers diverse applications including disease outbreaks, cartography, transportation safety, urban forestry, conservation decision making, wildlife movement, and hazards. GIS workflows that are emphasized in the lessons include understanding and exploring spatial data, hot spot mapping, spatial data integration, movement modelling, site suitability, and feature extraction from imagery through AI. Ethical lessons cover diverse topics from the importance of representative data, to the impact of redlining, to issues related to data privacy.

Using the modules

Instructors can use content from modules in their entirety or as component parts as is available at the website guidetothegeographicapproach.com. In their entirety, the modules are packaged as ArcGIS StoryMaps, and links to the ArcGIS StoryMap can be provided to students so they can work through the module “as is,” with no modifications. Recognizing that instructors may want to use a portion of the materials or mix and match different components to fit their own course sequence, we have designed the distribution system to be as flexible as possible. All components can be extracted from the StoryMaps and adapted to meet instructor needs. For instance, each module includes short videos explaining GIS concepts. We also include the written video scripts so instructors can easily make their own voiceover. Similarly, we provide suggestions for how instructors can recreate the problem-based labs using local data or examples to make the material relevant for learners. In short, all materials can be used individually and repurposed for instructor needs.

Each module is supported by instructor materials including: a document to introduce and overview the module, scripts of all videos, data links, assessment questions, and supporting lab materials (e.g. code or PDFs). The module introduction includes a module overview, a list of technical (i.e. software), and modular dependencies (i.e. prerequisite knowledge that is beneficial). Summaries of videos and each section are provided. There is also a list of geospatial competencies that map learning onto the 15 competencies that frame the *Guide to the Geographic Approach*, the GIS Certification Institute skills, and entries in the GIS Body of Knowledge. As well, we map the skills introduced in each module to Bloom’s Taxonomy, a framework that organizes learning objectives into levels of thinking, from basic knowledge recall to higher-order skills like analysis and creation (Bloom et al., 1956). Bloom’s Taxonomy is widely used in curriculum development providing a framework for logically developing skills and promoting both foundational knowledge and critical thinking. Table 2 is an example of the mapping of competencies provided in the instructor materials, for the healthcare access module. Data used in the module and assessment questions that could be used in evaluation are provided and are open access.

Ongoing curriculum development

Module development is ongoing, and the website guidetothegeographicapproach.com will continue to be updated with new materials. Forthcoming modules include partnership with experts in remote sensing, business, social science, and conservation. In addition, we invite community members to contribute content

Table 2. Module competencies and reference materials provided in the instructor materials for the health-care access module.

Concept	Description	GISCI	GIS&T BoK	Bloom's Taxonomy Cognitive	Bloom's Taxonomy Knowledge	Module
Spatial accessibility	Understand the quantification of spatial accessibility	202	- Modelling Accessibility - Location and Service Area Problems - Networks - Distance Operations	Understand	Concept, Procedure	Background
Edge effect	Understand edge effects in GIS operations	202	- Buffers	Understand	Concept	Technical
Edge effect	Use buffers to capture and address edge effects	202	- Buffers - Distance Operations	Apply	Procedure	Lab
Model builder	Conceptualize and build a workflow	603	- Geospatial analysis and spatial modelling - Evolution of Geospatial Modeling	Understand	Procedure	Technical
Stability test of service area	Examine model assumption and conduct stability test	205, 602	- Location and Service Area Problems - Error-based Uncertainty - Verification and Validation of Applied GIS Research	Understand	Concept, Procedure	Ethics, Further
Query polygon	Select and query polygon	601	- Spatial Queries - Structured Query Language	Apply	Procedure	Lab
Outlier	Use choropleth map to spot outliers	301, 602	- Types of thematic map - Map Analysis - Map Reading	Analyze	Procedure	Lab
2SFCA	Apply 2SFCA to calculate health care accessibility	603	- Proximity and Distance Decay - Distance Operations - Geospatial analysis and spatial modelling	Analyze	Procedure	Lab
Ethical review	Evaluate the ethical implication of accessibility modeling and consider alternative approaches to model development	603	- GIS and Critical Ethics - Professional and Practical Ethics - GIS&T and Local Government - GIS&T and Public Health	Evaluate	CO	Ethics

they are willing to share, such as an excellent lecture or lab activity, or an entire module. Guidelines are available for structuring content for easy integration into the existing framework.

A catalog and search tool are also in the works, which will allow the module components to be indexed and searched. At this stage, many of the initial modules use ArcGIS Online, providing materials for instructors who are in the process of transitioning materials to this platform. However, future modules will use a variety of software, including ArcGIS Pro and "pythonic" ArcGIS Notebooks, as the goal is to provide the best learning for comprehension and workflows. Future work will also focus on integration of AI into curriculum.

Conclusions

The updating of the core GIScience curriculum is an exciting opportunity to invigorate our community around a set of core competencies. The *Guide to the Geographic Approach* is also designed to reduce the burden of updating curricula by creating resources and platforms to share materials. Technology is changing so quickly that refresh cycles for curriculum will be important and open-source materials will benefit instructors and students. Also, through curricula, we can define our shared values, language, and priorities and provide leadership on how to incorporate ethics, applications, and impact in data analysis.

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