New AP® Course Proposal

Geographic Information Science and Technology

AAG
American Association of Geographers

PROFESSIONAL DEVELOPMENT

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GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY

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CONTEXT OF GIS&T IN K-12 EDUCATION

Ever since the publication of the National Science Education Standards (National Academy of Sciences 1995), a concerted and evolving movement has gathered momentum to make STEM-based learning more inquiry-oriented. The proliferation of models of teaching and learning where questions and investigations drive learning, while not new, still present challenges in their planning, implementation, and evaluation. In order to make the vision of inquiry-driven STEM education come to fruition, educators are calling for resources, materials, and tools to support STEM teacher preparation and foster the shift toward inquiry-based learning in classrooms (Wilder, Brinkerhoff, & Higgins, 2003; McClurg & Buss, 2007; Trautmann & MaKinster, 2012).

The importance of geospatial concepts, data, and technology in scientific inquiry and practices is cited throughout STEM education standards and frameworks, including Geography for Life: National Geography Standards (Heffron & Downs, 2012), the Next Generation Science Standards (Achieve, 2013), the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), and The College, Career, and Civic Life (C3) Framework for Inquiry in Social Studies State Standards (National Council for the Social Studies, 2013). An AP GIS&T course would therefore have broad appeal and apply to high school subjects across the curriculum.

High school courses in GIS&T have begun to appear in recent years, most commonly under the curriculum for Careers and Technical Education (CTE). Some states, including California, Illinois, New York, and Texas, have pioneered dual-enrollment options for high school students taking GIS courses, permitting them to earn college credit at a partnering community college.

The AP GIS&T proposal committee contacted the departments of education in every state to determine which states currently offer GIS&T-related courses at the high school level. Of the 34 states that responded to this inquiry, 23 states offer a GIS&T course in some form. Sixteen of these states offer a course or sequence of courses focused on Geographic Information Systems. Examples of high school GIS&T course names include:

- Geographic Information Systems (GIS) – this is the most common course name.
- GIS and Remote Sensing
- GIS and Cartography
- Geospatial Technology
- Spatial Analysis

Six states offer an additional 17 courses that incorporate GIS as an instructional support technology, but do not explicitly teach the concepts and principles of geographic information science. These courses include: World Geography, Cartography, Environmental Management, Service Learning, and Forest Management. Eleven states offer what could be considered advanced or honors GIS courses, such as Modeling and Simulation Technology, Applications of Geospatial Technology, Advanced GIS, Geospatial Industry I & II, and GIS Technology 2. Data on student enrollments in all of these courses are largely unavailable.

The proposed AP GIS&T course would complement the technical-training and skills development of most GIS&T-related high school courses under CTE, but it will go much further in introducing students to fundamentals of information science, spatial data, spatial database development and management, spatial reasoning, cartographic design, and other topics commonly taught at the introductory college level.

TEACHER PROFESSIONAL DEVELOPMENT IN GIS&T EDUCATION

GIS and other geospatial technologies have long been used to support classroom instruction across the curriculum. There are a wide variety of teacher professional development programs available in states to support the adoption of geospatial technology. These programs have developed a large cadre of teachers in every state who possess some of the conceptual knowledge and technical skills necessary to teach a college-level introductory GIS&T course, but many of them will first require additional professional development (especially content knowledge of geographic information science) to succeed with the AP GIS&T course as described in this proposal.

To assess what additional professional development will be needed to support AP GIS&T, the proposal committee compiled an inventory of known professional development programs in GIS&T education. Next, the committee aligned the content and pedagogy of those programs with the AP GIS&T course description, and considered the findings of any available published evaluations of those programs. Through this review, the committee identified three factors that appear to be essential for effective teacher training in GIS&T:

- Programs which support a variety of GIS platforms (both open source and commercial) tend to offer more opportunities to engage teachers and expand the options available for implementing GIS in school classrooms. The fit of GIS software as a teaching tool lies in the support materials provided, such as lesson plans, as well as the cost (if any) and technical infrastructure required. Table 1 presents a listing of some of the open source GIS software and freeware GIS available to educators. Another source of free GIS software comes from the Esri-ConnectED program. Through this >$1 billion initiative, Esri is providing free GIS software to public and private schools in the U.S. As of June 1, 2016, over 3,200 schools have received free GIS software from the Esri-ConnectED program.
- Teachers require a degree of independence and time to learn how to teach more advanced applications of geospatial technology, such as preparing students to do research, collect data, or complete service learning projects.
- Teachers who receive feedback from peers and mentors, both during and after the professional development program, are more likely to adopt GIS over the long term. Mentoring support is especially valuable for teachers experimenting with the technology. One major resource available to support these needs in the context of AP GIS&T is the AAG GeoMentor program. GeoMentors are GIS professionals and educators who work with schools to support GIS implementation in classrooms. As of June 1, 2016, there are 1,124 GeoMentors participating in this program (Figure 1).

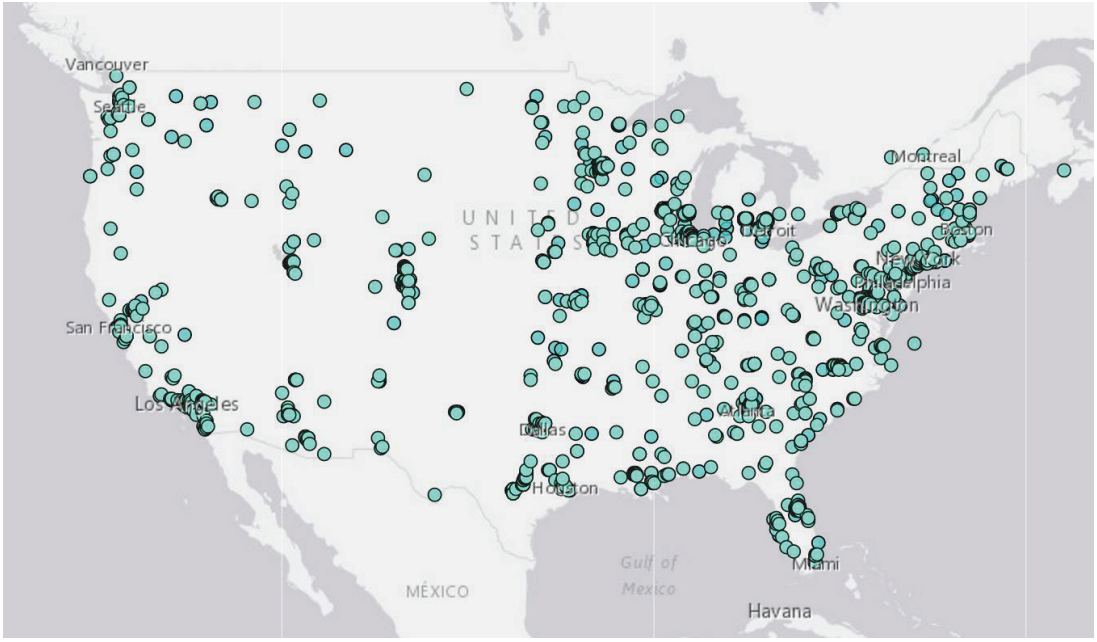

Figure 1. *AAG GeoMentors Network (as of June 1, 2016).*

Table 1. *Open Source and Free Geospatial Software (modified from source:* https://www.gislounge.com/open-source-gis-applications/*).*

Google Map	Users have access to virtual globes, maps, and geographical information. Platforms: Web browser
Google Earth	Google Earth provides users with the ability to navigate and explore geographic data on a 3D globe using a web browser. Platforms: Web browser
OpenGeo Suite	OpenGeo Suite is a geospatial platform for managing data and building maps and applications across web browsers, desktops, and mobile devices. OpenGeo Suite enables organizations to reliably manage and publish geospatial data. Platform: Windows, Linux, Mac OS
FulcrumApp	FulcrumApp offers applications to collect data in the field anytime, either online or offline. Data can be synced to a Fulcrum cloud account. Platforms: iphone, ipad, & Android devices
FlowMap	FlowMap is a freeware application designed to analyze and display flow data. This application was developed at the Faculty of Geographical Sciences of the Utrecht University in the Netherlands. Platforms: Windows OS
GMT Mapping Tools	GMT is a free, public-domain collection of ~60 UNIX tools that allow users to manipulate (x,y) and (x,y,z) data sets (including filtering, trend fitting, gridding, projecting, etc.). Users can produce Encapsulated PostScript File (EPS) illustrations ranging from simple x-y plots through contour maps to artificially illuminated surfaces and 3-D perspective views in black and white, gray tone, hachure patterns, and 24-bit color. Platforms: UNIX, Macintosh
GRASS	Geographic Resources Analysis Support System (GRASS) is the public domain GIS software application originally developed by the US Government. GRASS is probably the most well-known of open source and original GIS software applications. GRASS is a raster-based GIS, vector GIS, image processing system, graphics production system, data management system, and spatial modeling system. GRASS can be downloaded for free. Platforms: Linux, Macintosh, Sun Solaris, Silicon Graphics Irix, HP-UX, DEC-Alpha, and Windows OS Further Resources: GRASS
gvSIG	gvSIG is an open source GIS application written in Java. Platforms: Windows, Macintosh, Linux, UNIX
MapWindow GIS	MapWindow GIS is open source GIS application that can be extended through plugins. The application is built using Microsoft's .NET Platforms: Windows

OpenJUMP GIS	OpenJUMP GIS is an open source GIS written in Java through a collaborative effort by volunteers. Formerly known as JUMP GIS, the application can read shapefiles and GML format files. Platforms: Windows, Macintosh, Linux, UNIX
Quantum GIS	Also referred to as QGIS, Quantum GIS is an Open Source Geographic Information System (GIS). QGIS provides a spatial file browser, server applications, and web applications. It can be used to create, edit, visualize, analyze, and publish geospatial information. The GeoAcademy has created award-winning tutorials for QGIS training that follow the Department of Labor geospatial technology competency model (GTCM). More: Getting Started With QGIS: Open Source GIS Platforms: Linux, Unix, Mac OSX, and Windows.
SPRING	SPRING is a GIS and Remote Sensing Image Processing system with an object-oriented data model which provides for the integration of raster and vector data representations in a single environment. Platform: Windows, Linux, UNIX, Macintosh
TNTLite	TNTLite MicroImages, Inc. provides TNTlite as a free version of TNTmips, the professional software for geospatial data analysis. The free TNTlite product has all the features of the professional version, except TNTlite limits the size of Project File objects, and TNTlite enables data sharing only with other copies of TNTlite (export processes are disabled). The software can either be downloaded or ordered on CD. Platforms: Windows
uDig GIS	uDig GIS is a free, open source GIS desktop application that runs on Windows, Linux and MacOS. uDig was designed to use Open Geospatial Consortium's OpenGIS standards such as WMS, WFS, and more. One-click install allows users to view local shapefiles, remote WMS services, and even directly edit spatial database geometries. Platforms: Windows, Linux, Macintosh

EXAMPLES OF GIS&T PROFESSIONAL DEVELOPMENT

The following examples of GIS&T professional development programs are illustrative of many principles of effective practices in action. Although the proposed AP GIS&T course will require additional specialized professional development, as explained below, these examples attest to the feasibility of preparing teachers in every state to adopt and teach with GIS.

T3G Institute: Teachers Teaching Teachers GIS (http://edcommunity.esri.com/educational-roles/t3g-educators). The T3G Institute is a week-long training program for educators from public and private institutions at all grade levels, including college. During the training, participants learn GIS skills from Esri personnel and other educators. T3G also provides a variety of materials on the program's website that teachers can use to create GIS lessons in the classroom. Upon completion of the program, participants are expected to develop their own professional development programs for teachers in their communities (Figure 2).

Figure 2: *T3G professional development includes experiential learning and formal lectures. (Source: Joseph Kerski, Esri)*

Geospatial Semester (http://www.isat.jmu.edu/geospatialsemester/). The Geospatial Semester program is a collaboration between Virginia high schools and the Department of Integrated Science and Technology at James Madison University (Figure 3). The program engages high school seniors in geospatial projects during their final semester. In addition, the program offers 2-day introductory and advanced training sessions for Virginia teachers, and allows teachers to contact program representatives for mentoring support.

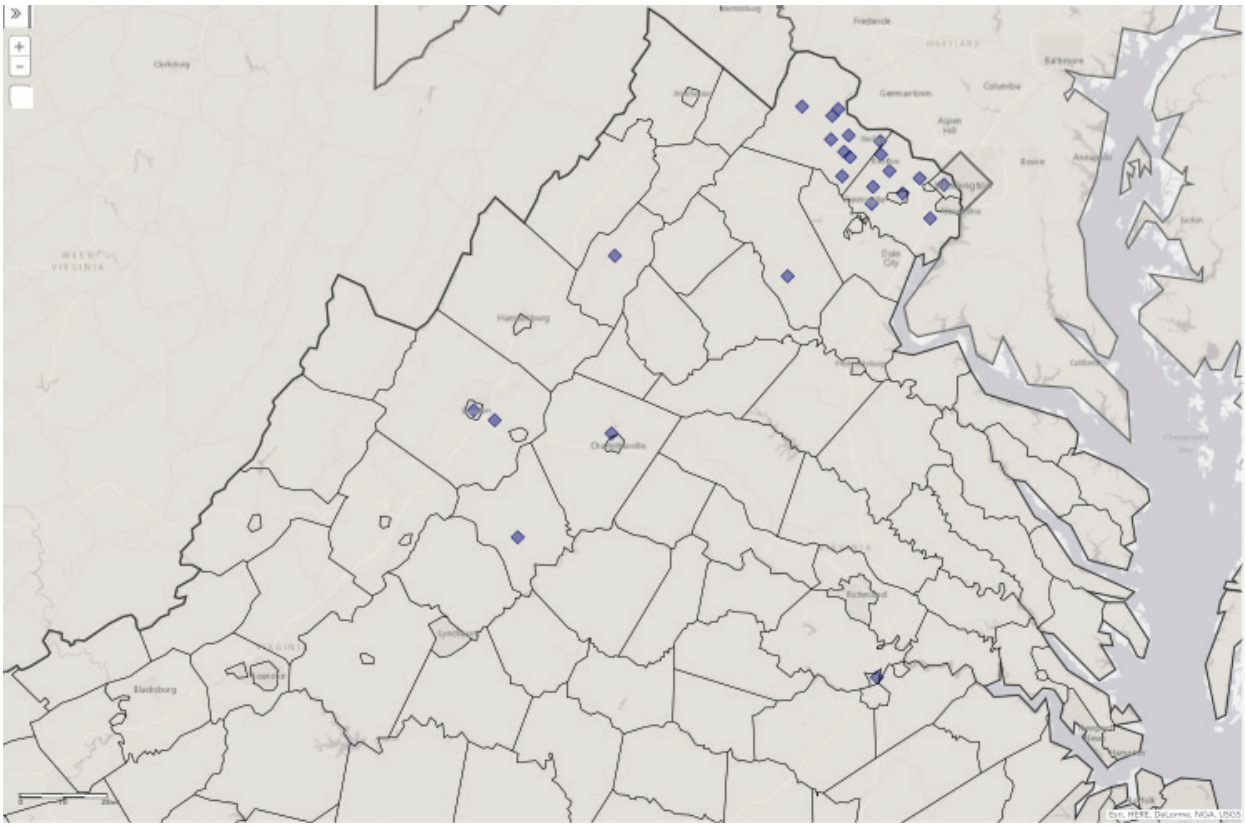

Figure 3. *Locations of high schools participating in the Geospatial Semester program (2015-2016) (Source:* http://www.isat.jmu.edu/geospatialsemester/map.html*)*

GeoTech Consortium of Western New York (http://www.nygeographicalliance.org/node/36). This program supports dual credit GIS course articulation between local high schools and Monroe Community College. The program consists of a two-day workshop, curriculum materials, and mentoring for teachers prior to and throughout the teaching period (Figure 4).

Figure 4. *Teachers receiving geospatial technology training at Monroe Community College (photo credit: NY Geographic Alliance).*

The National Geographic Network of Alliances for Geographic Education (http://alliances.nationalgeographic.com/index.php). Many Geographic Alliances, such as the California Geographic Alliance and the Virginia Geographic Alliance, provide GIS&T training workshops for high school teachers (Figure 5). For example, the Virginia Geographic Alliance offers face-to-face summer institutes and recently developed a 5-week online course "Putting Social Studies in its Place" that trains teachers to use ArcGIS Online and join the ESRI ConnectED initiative.

Figure 5. *The 3-day GeoQuest Workshop by the California Geographic Alliance supported 12 high school teachers from San Diego Unified and Sweetwater Union. (photo credit: California Geographic Alliance).*

The National Geospatial Technology Center of Excellence (http://www.geotechcenter.org/). The GeoTech Center has provided many online webinars, model course materials, and annual geospatial technology workshops for GIS educators. The annual workshops are created for both community college and high school teachers (Figure 6).

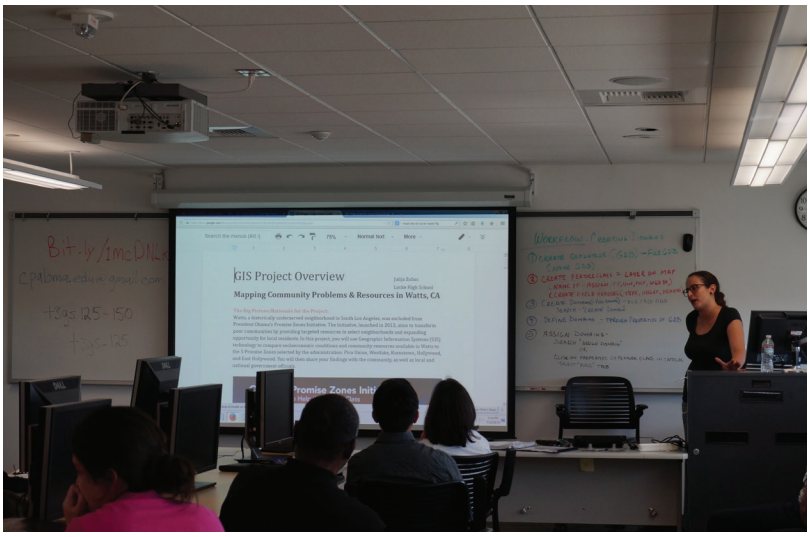

Figure 6. *High school teachers introduced their final GIS exercise modules for group discussion at the 2014 GeoTech Workshop (photo credit: GeoTech Center).*

Center for Science Teaching and Learning, Northern Arizona University (https://nau.edu/CEFNS/CSTL/Welcome/). Two professional development workshops at this Center are focused on geospatial technologies and targeted to STEM teachers of grades 6-12 (Figure 7). The workshop format is a hybrid 24-hour course offered throughout the academic year and includes a 35-hour summer institute for advanced training. Follow-up and support is provided to teachers throughout the year.

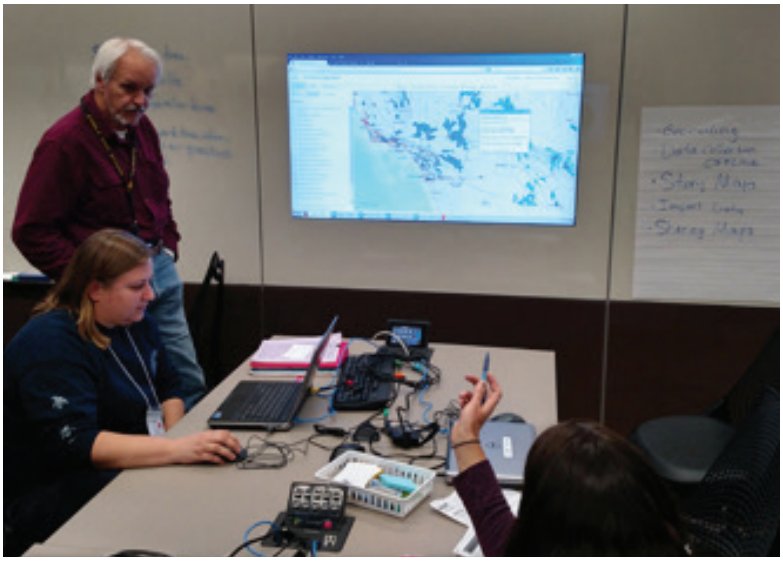

Figure 7. *Teachers discuss implementation ideas for geospatial technologies in their classroom (photo credit: Center for Science Teaching and Learning)*

Environmental Literacy and Inquiry (ELI) (http://www.ei.lehigh.edu/eli/). ELI is an inquiry-based middle school curriculum that uses geospatial information technologies. Its director, Dr. Al Bodzin, leads professional development workshops, which take place over 8 days. Through hands-on data collection activities, participant completion of computer activities, and content presentations, teachers are introduced to geospatial curriculum approaches, specifically Web GIS learning activities.

AP GIS&T PROFESSIONAL DEVELOPMENT RECOMMENDATIONS

The proposal committee recommends the development of an AP GIS&T Summer Institute in collaboration with the College Board. This forum is intended to train teachers in one location, and will cover the conceptual, technological, and pedagogical aspects of GIS&T. Following the model of existing AP summer institutes, the committee envisions a training agenda framed around 30 hours of training over a consecutive number of days (5-8 days), led by classroom teachers and/or professors to cover the course materials.

To create a consistent level of instructional knowledge and skills, a professional development institute for AP GIS&T teachers should, at a minimum, focus on the following areas:

> *Knowledge:* Teachers will need to know fundamental principles and concepts of geographic information science (as outlined in the AP GIS&T course description). Teachers will need to have an understanding of what constitutes spatial data, how spatial data are collected, and sources of error affecting the accuracy and utility of spatial data. Teachers must also be able to work with spatial data and perform an analysis using GIS. Additionally, teachers should learn the principles of analytical methods, data modeling, and geovisualization.
>
> *Skills:* Teachers will need to master a variety of geospatial skills to teach AP GIS&T. For example, teachers should be comfortable employing and demonstrating various GIS graphical user interfaces (GUI), particularly those associated with their GIS software platform of choice. It is important for teachers to have the ability to create, query, and manage databases (e.g., data entry, editing, and conversion). Teachers should have general cartographic skills, including knowledge of the use of map elements and projections. To answer geographic questions, teachers will need to use a GIS to analyze data, including, but not limited to, carrying out vector analysis (e.g. overlays) and raster manipulation (e.g. raster calculations).

Based on its review of existing GIS&T professional development programs (including those highlighted above), the proposal committee recommends the following design elements for a summer institute to support prospective AP GIS&T teachers. These recommendations are consistent with the best practices for professional development that were identified in National Geographic's Road Map for 21st Century Geography Education project (Schell, Roth, & Mohan, 2013).

1. *Context*: To build teachers' spatial analysis and reasoning capabilities, AP GIS&T professional development should teach these skills in the context of big ideas and contemporary problems (e.g., climate change, water resources, migration, urban growth, etc.). This will provide a robust geographical context for learning GIS and reinforce the idea that GIS is meant to support spatial analytical capabilities. A second strategy, recognizing that the context may not solely be geographic but may also be geologic or biological, etc., is to illustrate for teachers how GIS supports interdisciplinary teaching across the school curriculum. This broader focus will greatly expand the pool of potential adopters of the AP GIS&T curriculum.

2. *Learning environment*: AP GIS&T professional development should engage teachers through various learning environments, both in-person and online. The in-person experience would include hands-on and project-based approaches, as research suggests that active learning contributes to teacher learning (Claesgens et al., 2013). Many successful professional development programs extend face-to-face workshops through online video, web-based tutoring, and mentoring support after the workshop concludes. In the initial implementation phases, periodic follow-up with the teachers may be helpful.

3. *Materials*: AP GIS&T professional development should use teacher training materials (e.g., geospatial datasets, maps, lecture notes or slides, and lessons) that leverage teachers' prior knowledge and provide them with authentic experiences. This might take the form of collecting data and creating real-time maps in the field using a handheld GPS.

4. *Mapping software*: AP GIS&T professional development should not be reliant on a particular brand of software. There is a wide array of GIS software that includes free and open source options, many with commercial support, as well as proprietary software available for free through grant programs or free-tier membership models.

5. *Measures of success*: A future AP GIS&T professional development program should include an evaluation, with formative processes in place that identify areas that work and those that need improvement. With a research and evaluation plan, the professional development program can become a valuable research opportunity as well as a training resource. Knowledge and insights gained from this research and evaluation work will ultimately contribute to the success of the AP GIS&T course.

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