Building a GIS Workshop for High School Students

May 2021

A White Paper from the National Center for Sustainable Transportation

Meghan Orr, California State University, Long Beach
Ben Olson, California State University, Long Beach
Angelina Carballo, California State University, Long Beach
Alondra Garcia, California State University, Long Beach
Tom O'Brien, California State University, Long Beach

National Center for Sustainable Transportation

METRANS Transportation Consortium
USC | CSULB

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NCST-CSULB-WP-21-07	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Building a GIS Workshop for High School Students		**5. Report Date** May 2021
		6. Performing Organization Code N/A
7. Author(s) Meghan Orr, https://orcid.org/0000-0002-0134-9445 Ben Olson, https://orcid.org/0000-0002-2991-4020 Angelina Carballo, https://orcid.org/0000-0002-8847-0300 Alondra Garcia, https://orcid.org/0000-0001-5686-6186 Thomas O'Brien, Ph.D., https://orcid.org/0000-0002-6518-0263		**8. Performing Organization Report No.** N/A
9. Performing Organization Name and Address Center for International Trade and Transportation 6300 E. State University Dr. Suite 104 Long Beach, California 90815		**10. Work Unit No.** N/A
		11. Contract or Grant No. USDOT Grant 69A3551747114
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE, Washington, DC 20590		**13. Type of Report and Period Covered** Final Report (October 2019 – September 2021)
		14. Sponsoring Agency Code USDOT OST-R

15. Supplementary Notes
DOI: https://doi.org/10.7922/G20G3HF9

16. Abstract
Geographic information systems are an increasingly relevant tool being used in a variety of workforces. While education on GIS is well developed at the collegiate level and in workforce training programs, it is underutilized in K-12 settings. Research indicates that learning GIS can improve spatial and critical thinking skills in students, key elements for excelling in a variety of careers. Best practices indicate that teaching GIS through projects in a cross disciplinary setting (i.e., including math, science, and writing elements to projects), students may retain even more information about the subject matters and develop a greater interest in STEM and GIS related fields. Incorporating projects that are salient to student life such as themes of sustainability may increase student interest as well. Instructor fluency in GIS and mapping was found to be key to successful GIS education as well. When developing a GIS workshop, the authors recommend incorporating interdisciplinary projects that are salient to student interest, and pair it with a teacher educator workshop that highlights the benefits of using GIS in an educational setting. With the limited time of a single day workshop, focusing on gaining buy-in and explaining feasibility will be key to any successful workshop.

17. Key Words GIS, Education, K-12, Project-based learning, Workshops	**18. Distribution Statement** No restrictions.		
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 29	**22. Price** N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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Disclaimer

Acknowledgments

This study was funded by a grant from the National Center for Sustainable Transportation (NCST), supported by the U.S. Department of Transportation (USDOT) through the University Transportation Centers program. The authors would like to thank the NCST and the USDOT for their support of university-based research in transportation, and especially for the funding provided in support of this project.

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Meghan Orr, Ben Olson, Angelina Carballo, Alondra Garcia, and Tom O'Brien

Center for International Trade and Transportation, California State University, Long Beach

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EXECUTIVE SUMMARY

Geographic Information Systems, or GIS, are increasing in relevance and usage at all levels of technology platforms. Job prospects for young workers with GIS certification and experience are increasing, and pay is competitive across fields. Yet GIS remains vastly underutilized in K-12 education [1], with many young people having little awareness of GIS, its uses, and the wide range of opportunities available to young people adept at using GIS programs [2]. With a global pandemic, civil unrest, and economic uncertainty, arming young people with the knowledge and skillsets to pursue viable careers is an essential part of ensuring the continued growth of industries and stability of workforces for future generations.

This white paper sought to learn more about ways to successfully build a GIS workshop to introduce students and instructors to GIS education. By looking to past programs that have successfully integrated Science, Technology, Engineering, and Math (STEM) education and used it as a steppingstone to prepare a future workforce, this paper presents a set of best practices and recommendations for GIS education as well. In our research, we found that successful STEM and GIS education makes use of a few key factors:

- Incorporating career-focused learning opportunities such as internships, job shadowing, Q&As with professionals. Students who have access to mentors and professionals, especially ones who come from similar socioeconomic backgrounds may have an easier time envisioning themselves working in the field in the future, which can increase motivation.
- Using project-based learning to guide classroom instruction. Project-based learning gives students hands-on opportunities to practice the skills they are learning and gives them tangible finished products that they can refer back to and build on in future settings. GIS is more than just software and giving students opportunities to create their own projects with the software enables more fluent use of the programs and fosters creativity.
- Embracing a STEM philosophy by teaching in a cross-disciplinary style, such as combining math and science coursework in projects. When instructors from multiple disciplines are supporting students in GIS work, the skills being used become more easily accessible and students become more comfortable navigating the software and imagining their own uses for it.

Actual implementation of a GIS workshop can be quite difficult due to a number of barriers. Lack of awareness of the fundamentals of GIS and its uses can make instructor and administrator buy-in difficult. Without sufficient knowledge of the importance of GIS, program implementation may fail, even with well-developed curriculums. Part of the reason for this is the steep learning curve for instructors. Without sufficient background knowledge on GIS, instructors need to spend a significant amount of time learning the software themselves and may struggle to find adequate time to dedicate to that process. Administrator buy-in is

essential to allowing teachers the time needed to learn GIS and develop projects that will allow them to apply GIS in the classroom in a way that is engaging and relevant to their students. Furthermore, there may be technical challenges or limited access to the needed software or hardware to successfully implement a workshop. Economic inequalities in school districts and the current stay at home orders can exacerbate these challenges.

Despite these barriers, there are a number of factors that can help ensure success in building a GIS workshop, and even continuing to incorporate GIS learning and projects after the workshop is completed. We make the following recommendations for ensuring successful workshop implementation:

- Communication with administrators prior to implementation of any workshop. This can help ensure admin buy-in, which can ease difficulties with accessing available computers and other technological resources needed to conduct a workshop.
- Assess for technology needs prior to conducting any workshops. With distance learning and district funding being inconsistent, ensuring that each student has access to all the tools they need prior to the workshop will create a much smoother day-of experience.
- Incorporate teacher trainings along with the student workshops. These trainings would provide information for instructors on the benefits of GIS learning and project-based education, and ways to incorporate GIS into Common Core standards and competencies.
- Include an applied element to the workshop. Instruction should be more than simple demos with GIS software, but instead challenging students to create a finished project of their own. Ideally this project will be something directly related to their own life, which will increase engagement and interest.
- Discuss career opportunities and options with students. High school students often struggle to connect what they are learning with how it will benefit them in the future. Showing students the diverse career opportunities associated with GIS will help increase engagement in the workshop and potential long-term interest in the field.

Introduction

In an increasingly tech-reliant world, educators and leaders are recognizing that STEM-based education is an essential element for future success for young people. The world is rapidly changing, and there has never been so much uncertainty for the future as there is today. The country is facing an unprecedented pandemic, wildfires race across California, and concern for global solutions to address climate change have become increasingly prevalent. One thing that remains constant is that education and workforce development is a key aspect to success for our future. With such an uncertain world in front of them, providing students with skills and expertise that they can carry with them into their careers is an essential ingredient for their future success. STEM-based education provides many answers to these uncertainties, giving students the tools they need to prepare for their futures in the workforce, such as teaching problem-solving skills, and introducing applied learning concepts. One tool that is becoming increasingly relevant, though currently underutilized in the classroom, are Geographic Information Systems.

At its core, a Geographical Information System, or GIS, is data interpretation and meaning-making. What starts as individual data points becomes a map, a dataset, a synthesis of information. GIS helps people tell stories through data and build a more comprehensive and nuanced understanding of the data at hand. In an educational setting, GIS can help students learn how to think conceptually and syncretically, bringing in information from a variety of sources and modes, and learning the ways in which different systems inform each other. GIS has been shown to improve spatial thinking skills in students, which is an essential skill for any kind of work with datasets and applied sciences. Spatial reasoning and thinking skills have even become synonymous with general math skills for some educators [3]. Furthermore, bringing GIS into the classroom creates cohesive learning experiences that allow students to practice the skills and concepts introduced in other subjects, and add in applied concepts such as data interpretation and synthesis, mapping, and storytelling through data.

How do we bring such concepts into the classroom, though? Many instructors and educators at the K-12 level remain unfamiliar with GIS, its uses, and its value in the classroom setting. Research has shown that STEM education, and GIS specifically, benefits greatly from hands-on learning environments where students are engaging directly with the data and practicing using it in a variety of ways. Teaching GIS is less about teaching the software itself and more about enabling students to use GIS in a variety of manners across disciplines. In this way students absorb the methods and techniques needed to manage GIS software, but more importantly, they gain real-world skills in using data to analyze a wide variety of situations and circumstances, and how to present that data in a compelling way that will connect with their audiences.

At this time interest, funding, and manpower to house comprehensive GIS programs falls short of what is needed. Workshops provide an important answer to this problem. Portable, concrete, and goal-oriented, workshops give students an opportunity to be introduced to the concepts of GIS and immediately begin practicing the uses and techniques of GIS from day one.

Coupled with educator workshops on incorporating GIS into curricula, workshops can pack a powerful punch into a short session, and provide the seeds for lasting educational outcomes.

With a rapidly changing workforce that is increasingly tech and automation driven, concepts like GIS will only become more essential to the future workforce. GIS has become an integral part of a wide variety of fields, including transit, sustainability, urban planning, geology, and many more. As the technology improves and becomes more widely accessible, possible uses for it will only increase. Automation and technological advances increase every year, and they are an increasingly relied-upon aspect of the transportation industry. Amid the global pandemic, automation and tech-driven work has expanded exponentially. The need for a technologically adept workforce has never been more essential. The current transportation workforce is rapidly aging, and a need for younger workers that are equipped to master modern transportation technology and continue to bring innovation into the workforce will be essential as the industry continues to move through the 21st century.

Background

Teaching STEM

At the heart of STEM education is the concept that the classroom is the foundation of our future workforce. Learning arithmetic, trigonometry, physics and technology are not viewed as esoteric concepts suitable only for collegiate research and ivory tower study. Instead, they are the building blocks of the skill sets needed for the next generation of the workforce. With that understanding in mind, the approach to teaching STEM is invited to be radically different from traditional learning. If our goal is workforce development and skill acquisition, what is holding us to textbooks and worksheets? Certainly, concrete theoretical knowledge is an essential part of skill development, and time spent in classrooms learning and practicing specific aspects of a curriculum is not going anywhere, nor should it [4].

Yet moving beyond the simple mechanics of discrete academic coursework is the *why* behind learning any of these concepts. Knowing how to do a mathematical proof may be a satisfying skill for some students who are intrinsically motivated and curious, but for many students the question of the value of spending time learning these concepts may be disincentivizing enough on its own to prevent rigorous academic effort. The age-old jokes about how often in life one has been asked to use the Pythagorean theorem, while trite, rings true for many students. The STEM philosophy legitimizes that question by answering it, providing responses in the way of applied learning activities, career exploration, and concrete skill development that can be used in the workforce.

This acknowledgment of student questions about the value of their own education is a strength of STEM: the willingness to engage students in these concerns about the practical applications of their education, instead of dismissing these questions and providing vague reasons of education “being for their own good” fosters a sense of goodwill and trust between student and teacher, inviting the student to take agency and initiative over their own learning objectives. This implicit trust has a compounding advantage of not only encouraging more

engagement from students in the self-interested goals of workforce development and skill acquisition, which will benefit the general workforce pipeline, but also may have secondary education benefits including increasing student engagement and intrinsic motivation in scholastic activity.

How does STEM accomplish and implement these ideals? Applied knowledge has been the cornerstone of effective STEM education. This manifests in a variety of different manners, but perhaps best known is the concept of project-based learning. Simply put, project-based learning is built on the idea that people learn best by doing. A classroom that employs project-based learning philosophies often creates curated projects for students to practice and apply skill-sets in a real-world setting, helping students gain confidence and fluency in the skills being practiced, while simultaneously gaining experience in social and emotional learning skills such as conflict resolution, brainstorming, troubleshooting, and planning.

In 2015, Portland State University, in partnership with Oregon DOT, the National Institute for Transportation and Communities (NITC), and Portland Metro STEM partnership, developed a Common Core compliant STEM curriculum unit focused on transportation issues for elementary school students [5]. The program was piloted in five classrooms across two elementary schools in the Portland area. The curriculum began by engaging in a tour of the school grounds to determine problem areas on the campus, with both groups of students choosing to focus on their school's parking lots. The program's focus was on equipping teachers with the skills needed to develop future project-based learning opportunities for students by helping them develop an understanding of the real-world applications of math and engineering, how to connect those concepts to in-place curriculum requirements, and the process of connecting these concepts to real-world problems for students. The curriculum incorporated construction and planning books for the students to read, along with writing prompts that included letters home to families and journaling about what they were learning. The resulting curriculum incorporated exposure to relevant children's literature, writing prompts, and measurement activities in the school parking lot along with conceptual planning of parking lot logistics (how many handicap spots to include, directional flow, etc.). Students met with industry professionals and were given workplace safety gear (such as hardhats and vests) and measurement tools (such as measuring wheels) to simulate the real-life experience of such projects. After the data gathering activity, students went into groups and developed presentations for their plans to revitalize the school parking lot, which were eventually presented to school officials, reinforcing further analysis, writing, and speaking skills. Upon completion of the project, teachers reported that students were more engaged with the learning materials in this unit than in other learning experiences, and took more ownership over the learning process overall.

Career exposure is increasingly being seen as an integral part of an effective and holistic STEM education. A significant barrier to young people entering STEM fields, especially young women and people of color, is often the sense that there is no place for them in these fields [6]. All too often, this is not just a perception but a reality. Nationally, women make up only 24% of the STEM workforce [7], despite making up nearly half of the general workforce. Similarly, though

Black and Hispanic workers make up roughly 26% of the workforce, they make up only 16% of the STEM workforce [8]. Research shows that when young people are exposed to role models that they can identify with in prospective fields, it may increase their sense of belonging, thus encouraging them to remain in the field. Intentionally bringing in career mentors that are female and have diverse racial and ethnic backgrounds can help ameliorate perceived social barriers that may be contributing to inhibited desires to enter STEM fields. In the transportation workforce, while women make up only 15% of the workforce, there is greater representation of African Americans (17.9%) and Hispanics (5.47%) than the general population [9].

One way to address these challenges is to bring the careers to the students. Programs that match students with professional mentors in STEM fields, that offer STEM career days, or completely embed career tracking into their programs may offer unique opportunities to not only expose more students to the career opportunities that STEM study may hold for them, but also begin to build the future workforce by linking students with specific early career opportunities. One such school that does this is Phelps Architecture, Construction, and Engineering (ACE) High School, a career path high school based in Washington, D.C. [10], The program has eight distinct career tracks for students to choose from, some more traditionally blue collar (such as construction or welding) while others rely more heavily on technology and science such as the Cisco Networking, engineering, and other related tracks. The programs that more heavily rely on science and technology education use a college prep model, incorporating advanced placement classes and other college-readiness courses to enable success in college and university settings. Other programs, like the Mayer Youth Technology Corps in Chicago, take a more multi-faceted approach and incorporate summer institutes, after-school programs, in-school sessions, college residencies, and perhaps most importantly, internships into their program [11]. Using the time-tested model of internships for young students exposes them consistently for a period of time to many working professionals, gives them a multitude of opportunities to practice applying STEM skills, and lets them “try on” professional roles in STEM fields. At Mayer Youth Technology Corps, students overall demonstrated 9% more interest in STEM related fields upon completion of the program, and an additional 10% increase in interest for students that held internships. This kind of sustained exposure to professionals, applied practice, and discussions surrounding career opportunities can be an instrumental part in developing interest and pursuit of STEM paths for students.

While internships and job shadowing may be a sort of “gold standard” for exposure to STEM fields, school district budgets, time constraints, and competing interests may put a hamper on the feasibility of incorporating these experiences into academic programming at many traditional schools. Academic best practices need not rely on external programming to work to develop the critical thinking skills and holistic thinking needed to excel in STEM, though. Embedded learning is an in-class method that is becoming increasingly popular across the country, and has been shown to be effective in both teaching the core concepts and also fostering applied critical thinking skills and an interest in STEM generally. What is meant by embedded learning programs is simply dually-taught curriculums. Instead of siloing math, science, or technology into separate classes that do not overlap, educators can incorporate aspects of the classes together, or even co-teach classes and develop lesson plans that address

learning competencies from multiple subjects. Common core standards allow instructors to reference these competencies when developing lesson plans, which can help pinpoint what exactly should be emphasized and taught to support a specific concept. A study on embedding math into chemistry classes found the students expressed more interest in math and STEM related careers after completing the course than a peer group that took a chemistry-only course, while still maintaining comparable test scores on state-wide standardized benchmarks [12]. What this suggests is that there is nothing to lose by embedding courses, and only things to gain (practice in applied knowledge, exposure to ways of thinking that are conducive to STEM fields). Of course, successful embedding of courses is highly dependent on proficiency of instructors. If instructors are not fluent in the coursework that they are attempting to incorporate, or have significant knowledge gaps, this can cause disruptions in learning, and breakdown the efficacy of the classroom environment.

Teaching GIS

As an overall approach, there are clear benefits to the STEM philosophy. Homing in more specifically on ways to bring STEM into the classroom that is meaningful to students presents an additional challenge. GIS, or Geographic Information Systems, are becoming an increasingly integral part of both everyday life and STEM fields. GIS-related competencies such as problem solving and data analysis have been found to be top-priority skills in a variety of transportation careers, and careers in GIS are expected to grow by about 20% over the next few years [13]. The Geospatial Jobs Clearinghouse (GJC) is an online resource that collects GIS related jobs postings. While many roles are simply called GIS specialist, the focus of the work varies considerably based on the company or institution. The University of Notre Dame's Children's Environmental Health Initiative listed an analyst position responsible for the GIS components of community health research projects [14]. At the Rails to Trails Conservancy in Washington, D.C. an analyst would be responsible for maintaining data on trails and using GIS to assess the connectivity and accessibility of the trail network [15]. In larger organizations, GIS can have a strong IT component. IT managers may be responsible for implementing or maintaining an enterprise GIS deployment [16]. Because of its use in infrastructure and transportation, surveyors and civil engineering positions often list familiarity with GIS methods and software as a desirable trait [17][18]. Every day people enter their cars, open their phones to their GPS app, and commute to their office using GIS technology. Consider the online magazine LA Eater [19] which highlights popular restaurants and cuisine across Los Angeles County, and now incorporate GIS story maps to show potential customers where the restaurants are in their area, along with a brief description of the cuisine and a few choice photos. As the technology becomes increasingly user-friendly and the average reader becomes increasingly tech-savvy, GIS will continue to be incorporated into ever more pedestrian applications. GIS incorporates spatial thinking skills, a skill underdeveloped in many young students today [20], due in part to a lack of map-based education in K-12 schooling. Illustrating the utility of GIS to students can be an integral part of gaining interest and student buy-in; when students realize that they may already have familiarity with basic applications of GIS, it demystifies the technology and its uses.

In the classroom, GIS has been found to be an effective way to teach geography and spatial thinking skills. Rød , Wenche and Nilsen explain that in Norwegian education systems, geography is described as a "synthesizing subject" due its incorporation of natural and social sciences among other disciplines in its approach and uses [21]. They describe GIS technology as being a powerful ally in geographic education for its incorporation of educational subjects such as math, statistics, and natural science, thus emphasizing the synthesizing nature of geography. One aspect of geographic learning that is key to success in the field is developing sufficient spatial cognition skills; the ability to conceptualize the maps and geography being studied spatially.

Like STEM education generally, students respond well to GIS education that is project-based and hands on. There is a significant learning curve when introducing GIS, because of the complexity of the software, but when the learning is paired with project opportunities, student engagement is higher, which can improve motivation and follow-through for students learning the software from scratch for the first time. In 2004, Sarah Bednarz at Texas A&M University led a feasibility study on implementing GIS learning in the classroom [22]. Teachers were first provided instruction in how to use GIS software. Many instructors preferred teaching GIS in a discrete manner, and did not move on to integrating the software into any classroom projects. However, the teachers that were able to "problematize" their curriculum to incorporate projects that would require GIS software reported the most success with teaching the software. While this method asks more of the instructors in terms of curriculum development and planning, the benefits to students are significant and worth investing in. Problematizing curriculums can show up in a number of ways – it can be used quite fluently in geography and history classes, for example. A classroom unit studying the history of the silk road could research where different raw goods were being developed, and what countries they were traded with; this information could then be visualized as a GIS map to illustrate the development of the silk road trade over time. Environmental studies is another area that lends itself well to GIS tools as a way to create hands-on learning experiences, giving students opportunities to visually conceptualize where resources are developed, shipped to, used, how it impacts natural environment, migration patterns of animals, and more.

Recently, a CSULB Center for International Trade and Transportation GIS Research Assistant created a story map (available here[1]) that showcases the benefits of teaching GIS to K-12 and a way to integrate GIS into K-12 curriculum. The story map, "Visualizing Sustainable Transportation Choices for K-12 students" presents the importance of teaching K-12 students about GIS and uses the topic, sustainable transportation as the subject matter to engage students in learning geospatial software. A GIS activity is created and displayed in the story map; in the activity students learn how to map their routes to school while measuring their transportation carbon footprint based on a chosen transportation choice. Students are able to directly connect how the choices they make (i.e., riding a bike or taking the bus to school) can impact their carbon footprint, and map that data visually. According to Esri, visual presentation is an especially effective way of transmitting this information to students [23]. Mapping

[1] https://storymaps.arcgis.com/stories/b0a67a88a3484864be4ae8ef81d7fa1f

students' daily commute can connect GIS with reality, which can spark curiosity, and increase their intrinsic engagement with the material. This project specifically chose the topic of carbon footprints in transportation, given the increased interest in global climate change and sustainable alternatives to carbon fuel. Integrating high-interest topics such as sustainability into GIS education can further maintain student interest while simultaneously giving them the opportunity to apply spatial thinking and STEM skills. Introduction to GIS in a K-12 setting gives students an advantage over peers receiving more traditional education, by giving them opportunities to enhance their critical spatial thinking skills with collecting, analyzing, and visualizing data.

Furthermore, as an increasingly relied-upon tool in the workplace, GIS education may be a key factor for the future of career-focused educational programs. GIS stand-alone certificate programs and specializations are being incorporated into vocational and collegiate academic programming that is recognizing the expanding need for a GIS-knowledgeable workforce. Certificate programs such as the GIS and Geospatial Technology Certificate offered at UCLA extension [24] offer foundational coursework teaching students how to use GIS software (such as Esri ArcGIS and QGIS), cartography, and spatial analysis. Other programs provide even more career focused support, such as San Bernardino Valley College's GIS certificate [25], which also incorporates GIS work placement, and independent study. In 2019, CITT partnered with Los Angeles Technical Trade College (LATTC) to pilot a GIS course, which resulted in students gaining skills in working with traffic data in Los Angeles and learning how to present the data as a visual storytelling device through the development of story maps like the one linked here[2] made by students in the program. Programs such as these are designed to situate students to be prepared to enter the Workforce as GIS technicians or in positions that would require some use of GIS technical skills in their jobs. At the more advanced level, there are programs like the GIS certificate at California State University, Long Beach [26]. This flexible certificate can be incorporated into Bachelor's or Master's degrees in geography, or as a stand-alone Baccalaureate certificate in GIS, and serves as an excellent bridge to Master's programs in GIS. Like the more foundational programs, the certificate offers coursework in GIS software, cartography, and spatial analysis, but also incorporates more advanced coursework in applications of GIS, remote sensing, and advanced cartography. The increase in applied and advanced coursework makes this program well-designed to set students on a career trajectory for GIS and mapping.

Barriers to Successful GIS Learning

Despite the academic and workforce development benefits of incorporating GIS into K-12 educational programming, there are significant barriers to effective implementation that can make it difficult to effectively teach the concepts in a classroom setting. Many teachers report difficulty learning software proficiently enough to teach it to their students [22]. Teachers may not have sufficient planning time to learn the software, requiring them to put in a significant amount of unpaid extra time to master the software. They may underestimate the amount of

[2] https://arcg.is/1niGv9

time they will need to spend familiarizing themselves with GIS, putting them in a position of being unable to complete GIS units with students due to lack of preparation. GIS software also offers its own complexities, which can make it difficult for instructors to independently master it without a sufficient background in computer science. Teachers that are able to master GIS proficiently enough may find themselves facing the same challenges in the classroom when they begin to introduce the concepts to students, especially for those without basic computer fluency. The amount of time required to fully explain the software to a level of sufficient independent usage can create a significant barrier, eating away vital class time that teachers need for other subjects. Many classrooms lack the flexibility due to school district curriculum requirements to be able to devote the amount of time needed to teach GIS to students, even if they had the motivation to work with students and troubleshoot computer problems.

For teachers who have a sufficient understanding of GIS and the motivation to work with students to achieve mastery, they may still face administrative hurdles that can impede effective GIS instruction in-class. In her 2004 report on GIS instruction in schools, Bednarz found that many teachers struggled with implementation due to simple logistics issues, such as inability to reserve computer labs for enough time to teach the students the software [22]. In-class computers or even district-distributed laptops could circumvent this access issue, although funding for laptops is highly dependent on state and local funding. Even when instructors are enthusiastic about dedicating enough class time to master GIS software, administrators may not have the same commitment to GIS instruction. This is often due to a lack of understanding about the benefits of GIS education, the purpose of GIS in the classroom, and how it fits into a comprehensive STEM education program. Uncooperative or uninterested administrative staff can effectively kill even the best laid GIS program plans before they even begin implementation, due to the lack of support both in resources and approval of teacher planning time. In the same vein, many instructors reported that a lack of a cohesive network of instructors to troubleshoot and plan with can make implementation especially difficult. For teachers that found themselves the only instructors implementing GIS programming in an entire school, the lack of support proved especially daunting.

Finally, insufficient pedagogical and curriculum development skills can prevent fluent implementation of GIS in the classroom in a way that is meaningful to students and creates lasting educational experiences. What is meant by this is not that instruction in these classrooms is subpar generally or that the teachers are not capable of teaching GIS, but that effective GIS instruction that is problem or project-focused requires a very different form of instruction than traditional learning modes, which can prove challenging for teachers to transition to smoothly. Creating project or problem-based learning opportunities is time-intensive for instructors, requiring them to reverse-engineer learning opportunities that necessitate GIS software. Instructors that are only just becoming familiar with GIS themselves will require support in developing creative ways of using GIS to teach common core learning competencies. Furthermore, Bednarz reports that many instructors are not familiar with the potential uses of maps in the classroom [22], which can lead to difficulty identifying places in the curriculum where implementing a GIS mapping project may prove useful. U.S. education is notoriously weak in geography [1], and this may extend to teachers as well. Most teachers

themselves were educated in the American public school system, and may not have been exposed to sufficient map-based learning to prepare them for teaching students how to read and use maps across disciplines.

Addressing GIS Pedagogical Barriers

With these significant barriers to effective GIS education in classrooms, how do we resolve them to create cohesive, high-quality GIS learning experiences for students? Central to implementing any new programming in academic environments, whether it is a single-day workshop or a more comprehensive curriculum shift, is gaining support from administration. When principals and other administrators are aware of the intentions and values of a program, and view it as being a worthwhile investment for the school, the path is paved for teachers to incorporate programming more thoroughly into their program. A cooperative and involved administration will champion the incorporation of GIS into the classroom and incentivize the process. Supportive administration will be involved in coordination of securing licensed software for teachers and providing sufficient training and professional support in how to use the software. With a supportive administration, navigating challenges such as securing sufficient computer lab time, or negotiating enough time in the classroom to adequately teach GIS concepts in class will be more easily addressed. Providing sufficient training and support for classroom teachers is a key part of developing a GIS program that can be successfully implemented long term. With sufficient training, curriculum support can be incorporated and will enhance teacher's "capacity to effectively use" geospatial technologies [32]. Implementing training will address the issue of teachers not having adequate knowledge and skills in GIS and will therefore support student's development of spatial thinking skills.

Workshop Model

Ideal best practices involve high levels of teacher training, structural and administrative support, access to Esri software and sufficient classroom learning time, and instructor planning time. This is often not feasible or practical for schools for a number of reasons. The amount of time and energy needed to become proficient enough in Esri to incorporate it thoroughly into a classroom setting is prohibitive for many schools due to a variety of reasons, including low interest, low computer fluency in instructors, lack of support from staff, or insufficient funding to support the needed technical support and training to deliver effective GIS lessons. Current social distancing orders have placed a large majority of students into remote learning situations, further complicating teacher and student ability to navigate complex data systems, especially for communities with inconsistent access to computers, WIFI, and app-based programming.

The workshop model can be an important entry tool for schools and students facing these kinds of barriers. Workshops are brief programs that can introduce students to a topic in a "crash course" model through a combination of passive instruction and applied learning. The goal is not proficiency or fluency in the topic, but instead engagement and awareness of the topic, and an opportunity to practice or apply the topic in a student setting. In the context of GIS, that can involve brief instruction on what GIS is, how it works, and what it is used for, followed by

applied GIS activities that can allow students a chance to get their feet wet and get familiarized with the concepts used in GIS software. The Center for International Trade and Transportation (CITT) has a long history of engaging with K-12 learners and bringing workforce topics to students in a way that can broaden student perspectives on future career opportunities and begin to introduce them to technologies that they may not have previously been aware of. Past workshops have included a "GIS Day" program that can serve as a model for future GIS days and related workshops. The 2018 GIS Day workshop was held at Cabrillo High School in Long Beach, California. Cabrillo high school has a longstanding relationship with the Port of Long Beach and CITT through its Academy of Global Logistics program [27], a career-track program offered in the school designed to help support students interested in pursuing careers in logistics and business. Cabrillo high school is an ethnically diverse school (68.5% Latino, 14% African American, 9.1% Filipino, 3.4% non-Filipino Asian, and 1.6% Caucasian) with high rates of economic instability (86.9% of students receive free lunch) and other barriers such as limited English proficiency (31% of the student body) [28]. Despite these barriers, student success in the AGL program has been measurable and consistently growing. Chronic absences have decreased among AGL students, and rates of students pursuing AP classes has increased from 6% to 17%, with overall graduation rates improving as well for students in the program. The 2018 workshop included a brief lecture facilitated by GIS research assistants at CITT, where they laid out the foundations of GIS, story maps, and how they work together to create data-driven storytelling that can connect real-life situations and information with readers. The workshop also highlighted career paths for students that use GIS or are GIS-focused, such as archeology, software development, urban planning, land surveying, and more. Given the career focus of the program at Cabrillo High School, this was an essential aspect of the workshop that helped garner student interest and increased student buy-in, as past research has noted. Following the lecture portion of the workshop, the facilitators transitioned into the applied portion, which included a crash course on navigating Esri software and how to build a story map. The rest of the time was spent supporting students as they built their story map, which was focused on identifying landmarks in the D.C. area, the subject of another class exercise.

A successful GIS day would incorporate these key components that worked well from past endeavors—namely incorporating a projects portion, using story maps, and highlighting career opportunities for students—and expand it based on best practices within the field. One of the biggest takeaways from successful use of GIS in the classroom is the integration of the technology into everyday curricular activities. While mastering Esri software in a single workshop is impractical, there are a variety of excellent free or low-cost simplified GIS programs available that are student and teacher-friendly. One of the best-known programs is Google Maps, which has a create-your-own-map program available on the desktop version of the site, under the "my maps" tab. The map creation page allows users to create layers and pin important sites within a selected zone, much like professional level GIS programs. Figure 1 below provides an example of a simple GIS map in Google Maps made by a student in the CITT Freight Academy, a workshop held by CITT in December of 2020. Ideally, a GIS day workshop would involve a teacher instruction component that would show teachers how to navigate and build a personal map in Google, provide curriculum ideas on how to incorporate GIS mapping into classroom activities, and highlight the academic and career benefits of infusing GIS into the

classroom. Esri's educator web page [21] has a classroom guide with a number of recommended curriculum activities that use mapping and GIS to teach a variety of concepts. These activities include story maps, which build narratives using maps, GeoNews, allowing students to visualize current events in a map-based presentation, along with more mathematical activities such as Quantitative Results, which uses Esri mapping software to create problem solving activities like determining available land for habitation in a region. Whether schools decide to invest in the more comprehensive Esri programs (such as the ArcGIS for Schools bundle, available for all public or private K-12 programs in the country) or stay with more entry-level programs such as Google Maps, there are a variety of lessons that can be taught and made more relevant through the use of project-based learning with mapping technology.

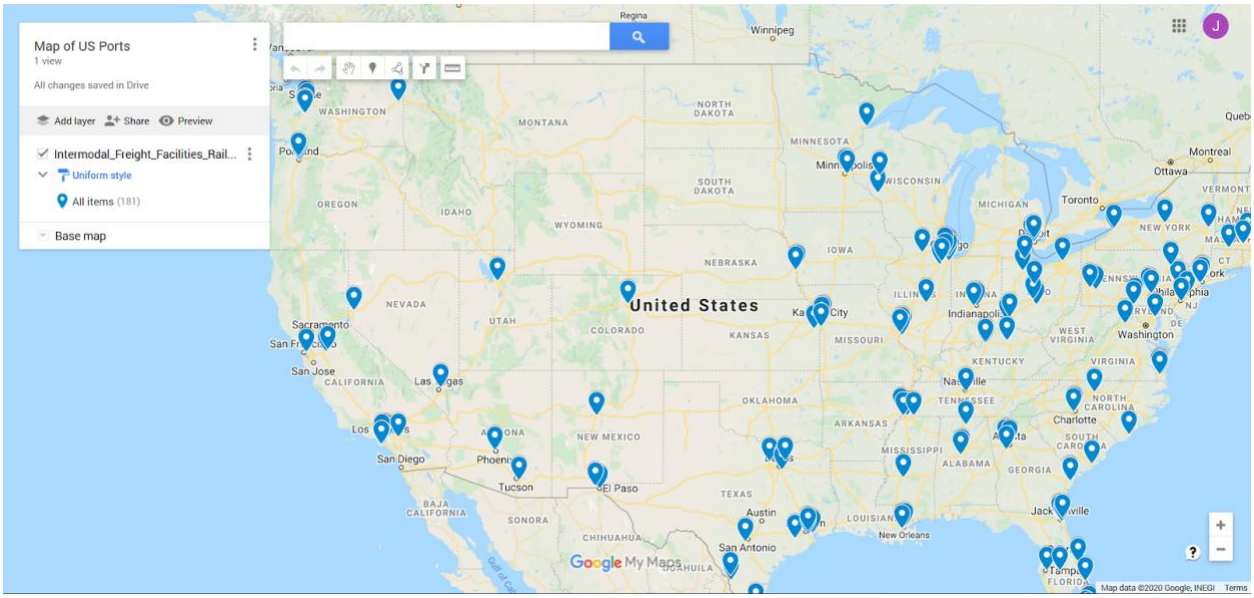

Figure 1. CITT Freight Academy student map of US Ports with data imported into Google Maps.

Finally, a comprehensive workshop will include an element of competition. While when taken to its extremes, competition can be unhealthy and breed negativity in classroom environments, collaborative and cooperative forms of competition can build skills in communication, develop agency and academic self-concept, and increase intrinsic motivation in the learning material [29]. Furthermore, a competitive element allows students the opportunity to present their materials, giving further practice in public speaking and developing presentations. The positive competitive atmosphere can serve as a motivating factor for students and encourage engagement for students that might have only had a passing interest in the topic otherwise.

Developing the Workshop

Technical and Institutional Infrastructure

To successfully implement a GIS workshop for high school students, students will need to be provided with adequate technical infrastructure. Due to the current global pandemic and social distancing requirements, many academic communities are participating in distance learning, and programming should be planned based on those circumstances. Beyond computer access and Esri Software, students will need stable internet, video call accounts to allow them to receive instruction from teachers and workshop facilitators, along with Esri online accounts. Under normal circumstances, students would have ample access to these resources in a classroom environment, with computer labs, school WIFI, and in-person instruction. Developing a successful GIS workshop day will require consistent coordination with instructors and administration to ensure students have easy access to all materials needed for the workshop. These needs will vary from district to district. In Los Angeles, for example, poverty rates hover close to 20% of the population, and only around 80% of the population has access to consistent internet connection. In response to this inconsistent rate of internet access, Los Angeles Unified School District has worked with the city and secured $100,000,000 to provide laptops for every student in the district, along with internet access for students that did not currently have access. This project resulted in 98% of students having sufficient internet connection and laptop accessibility. In another NCST city, Burlington, Vermont, COVID-19 cases have been much lower, and students have been able to attend school in a distance learning environment, leading to fewer barriers to adequate technical infrastructure for the program. Each school district will have its own COVID-19 related learning policies in place, and an effective GIS workshop will need to be flexible enough to be able to be implemented across in-person and online settings.

Instructors should anticipate some troubleshooting difficulties as students adjust to a new computer program, navigate potential internet connection issues, or face other unforeseen circumstances. It is important that all necessary materials are made accessible for each student prior to the GIS workshop day, as these tools will provide a successful learning course. Esri's ArcGIS for schools bundle provides free access to all K-12 students in the U.S. Classrooms or schools implementing a GIS workshop will need to be in touch with Esri prior to the GIS workshop day to determine how many student codes are needed, how the codes will be distributed to students, and what support will be available through Esri should any troubleshooting needs arise. A smoothly run GIS workshop day will provide teachers with the information they need to support students in setting up the Esri software, and ideally will already have the ArcGIS bundle set up for students prior to the workshop. If ArcGIS is not able to be set up before the workshop, instructors and workshop facilitators should build in ample cushion time to allow for technical difficulties on students' parts and be prepared to troubleshoot ArcGIS installation with students.

Finally, an ideal workshop day will include a mini workshop for teachers as well. This workshop would offer instructors a brief opportunity to familiarize themselves with Esri and other GIS software, as well as learn about the value of incorporating GIS into the classroom setting. Teachers could participate in a brief GIS activity, such as some of the ArcGIS 5x5 activities – a

set of 5-minute practice activities that requires no background in GIS or login information to do successfully. More than just introducing teachers to GIS, the workshop would highlight the benefits of project-based learning, and how GIS both facilitates project-based learning, and is also a fast-growing piece of modern technology that can open career opportunities to their students. Providing sample lesson plans that demonstrates to teachers what skills GIS can target in the classroom will be an essential part of underlining the value and usability of GIS. Sample lesson plans should be matched to age appropriate common-core outcomes and objectives, further demonstrating the utility of GIS in the classroom. Furthermore, identifying Common Core objectives and outcomes builds rapport with teachers and signals to them that the facilitators are aware of the multiple layers of expectations that they are managing in a classroom setting -not only classroom instruction and behavior management, but district, state, and national standards of comprehension in students. By demonstrating GIS facilitators' understanding of these expectations and communicating that incorporating GIS can help address those standards, the likelihood that instructors will continue to use GIS concepts and lesson plans after the workshop is increased.

Sustainability and Careers

Climate change and sustainability has become a topic of increasing concern for policy makers and transportation professionals. Young people have shown a particular concern and interest in this topic, inspired in part by young climate activists such as Greta Thunberg and increasing calls for greener technology and energy sources. GIS technology can play an integral role in sustainability research and development, and provides an excellent topic for students to begin to explore GIS in an applied manner. For these reasons, focusing GIS activities on sustainability provides an excellent theme that touches on current events, career paths, and is an area that has increasing student buy-in.

A proposed workshop would include a lecture with a theme that focuses on transportation and sustainability and the role that GIS plays in those fields. GIS research assistants at CITT have been developing a story map about ways that young people can incorporate sustainability into their life, titled "Visualizing Sustainable Transportation Choices for K-12 students" (link available here[3]). This story map would be able to serve as both an educational activity for students surrounding making sustainable choices, and also serve as a reference story map for the students to review. This model incorporates best practices of project-based learning that is current and addresses K-12 learning outcomes, providing an additional model for instructors interested in continuing to incorporate GIS project learning after the workshop day. Examples of the activity would be presented to the students, GIS tools and functions applied in the activity will be introduced, and how to calculate CO_2 footprint will also be presented. Researchers will identify grade-appropriate Common Core and objectives that this lesson addresses and communicate them to classroom teachers, allowing teachers to connect the lessons to national standardized benchmarks. Once all students are given enough time to complete the activity, they will be encouraged to present their findings. The purpose of this

[3] https://storymaps.arcgis.com/stories/b0a67a88a3484864be4ae8ef81d7fa1f

exercise is for students to utilize GIS as a means of discovering their individual contribution to greenhouse gas (GHG) emissions.

Finally, connecting the relevancy of what the students will be learning in the GIS workshop with real-world examples and career paths will be an essential part of the workshop presentation and group discussion. Presenting personal stories for the students to hear will help them be able to see themselves using these skills in the future. Any presenters that are skilled in GIS technology should share what brought them to GIS, and what their current or future career path entails for them related to GIS. Students should be exposed to a wide variety of potential career opportunities that use GIS, and in what capacity it is used. Research suggests that students are more interested in careers that they perceive as being creatively involved and relevant to their life [30]. For girls in particular, they may respond better to messaging that focuses on the helping aspects of STEM work, and how it can improve the world. Highlighting areas of GIS work that have contributed to human and environmental well-being may be an essential aspect of GIS careers to emphasize to maintain female student interest. For many girls, negative societal messaging about who can do STEM and technology (boys) and who cannot (girls) runs a danger of being internalized and can lead to insecurities surrounding their ability to excel in these fields. One way that researchers have found to combat those attitudes is to make a small word change -instead of talking to girls about *being* scientists, talking to them about *doing* science [31]. This may relieve some of the conceptual pressure to "be" someone that they might not see themselves as, and instead allow them to connect what they are already doing in their classes, and in the case of GIS, every time they take a bus or use Google maps, to what they could be doing in the future in their careers.

Implementation

Timeline

The purpose of this timeline is to showcase a proposed timeline for the workshop presented in this paper. With the timeline of the workshop being proposed, this is not a formal plan and can be subject to change with further development. The following next steps are recommended for implementing a successful GIS workshop across the four NCST universities:

June 2021

- CITT and NCST partners meet to discuss the proposal and plan for a GIS workshop day
- CITT will continue developing the workshop curricula

July 2021

- NCST partners will Identify and contact a suitable high school to host the workshop
- NCST partners will Identify an appropriate GIS-knowledgeable partner at each university location
- NCST partners will Identify and contact a suitable liaison at each high school who can assist with coordinating the workshop

August 2021

- CITT will confirm dates and times of workshop with all necessary partners (high school liaisons, GIS-knowledgeable partners, NCST partners, CITT research assistants)
- CITT will confirm school sites are equipped to host the GIS workshop
- CITT will present the workshop curricula to NCST partners for review

September 2021

- CITT research assistants will present GIS day workshop to high school students at NCST partner schools
- CITT research assistants will present GIS educators workshop to high school instructors

Identifying Ideal Partners

Key to a successful GIS Day workshop will be working with schools and instructors equipped to support students through the workshop and carry GIS activities into future school curricula.

Ideal high schools will:

- Have a careers track or a technical aspect to their curriculum
- Emphasize and promote STEM education with their students
- Have sufficient technological resources for students to complete the exercises
    - Laptops for each student
    - Wi-Fi access
- Have staff capable of supporting students through technical challenges
- Be learning in a remote or hybrid learning format

Ideal school liaisons will:

- Be sufficiently technologically capable of supporting students through technical challenges
- Have a focus or interest in STEM or GIS learning
- Be committed to assisting with coordination of time and resources at host school
- Be able to maintain regular contact with CITT throughout the planning process

Proposed Workshop Agenda

Following the workshop and student development of their projects, we propose a competition, where a small number of participants from each school are selected as finalists and are given the opportunity to present their projects and compete against students from other NCST affiliated schools. This would present a unique scholastic opportunity for students and create the opportunity to introduce an intrinsically motivating factor into the workshop day.

GIS High School Workshop: 70-95 minutes

- GIS Presentation: 25-35 minutes
    - What is GIS
    - Define spatial thinking, data layers, and other fundamentals
    - How to collect/search for/use data
    - What is a story map and why use them
    - Where and why to study GIS
        - Identify lucrative companies hiring GIS professionals to build motivation and interest from students
        - Identify nearby schools with certificate or degree programs in GIS
        - Provide example career pathways
        - Highlight helping professions to encourage female student interest [24]
- Story map activity: 45-60 minutes
    - Students will be provided with a model story map
        - https://storymaps.arcgis.com/stories/b0a67a88a3484864be4ae8ef81d7fa1f
    - Students will be provided with a choice of datasets to create a story map on some aspect of sustainable transportation
    - Introduce students to story maps and have them start one using the basics they have learned
- Student presentation and competition: 60-90 minutes
    - Students will briefly present their story maps to the class, the most creative and thoughtful of which will be chosen to taken part in the competition with other NCST affiliated schools

Teacher workshop: 60-75 minutes

- GIS presentation: 40-50 minutes
    - Define GIS
    - Why to introduce GIS into the classroom
        - Improves spatial thinking skills
        - Improves math skills
        - Improves problem solving skills
    - Why problem or project-based learning
        - Reinforces learning
        - Shows students relevance of data science
        - Teaches how to apply data to real-life situations
    - Google maps for GIS

        - Provide sample mini lesson plans that incorporate data science and Google maps
        - Identify Common Core objectives that each lesson plan addresses
- GIS Google maps activity: 20-25 minutes
    - Provide data set for instructors
    - Upload data set to Google maps
    - Identify Common Core objectives this lesson addresses
    - Identify complementary Common Core objectives (ex. writing assignments on the components of the map)

Conclusion

Effective GIS education for K-12 is still in its early stages in the U.S [13]. Though schools in the U.S. have increasingly worked to emphasize the importance of STEM education, implementation is still weak, and American students consistently lag on the global stage particularly in areas of math and science [3]. American schooling systems tend to be less focused on mapping and geography in recent years than in previous generations, leaving educators at a loss about how to incorporate GIS or unclear about the relevance of these programs [25]. Yet geotracking, mapping, and visual data visualization are becoming increasing relevant skills for the 21st century workforce, which high school students are only a few short years away from entering. The need for high-quality map and data-focused K-12 educational programming for both students and teachers is clear.

The future of education may look very different than traditional education systems today. There is a growing public discourse surrounding career-focused education that gives students the tools they need to be workforce or near-workforce ready when they graduate from high school. European systems of internships and career programs serve as an excellent model for future educational programming and have been gaining increasing attention stateside. Even in traditional academic programs, applied learning is increasingly recognized as a key component to effective learning that gives students opportunities to practice what they are learning, and apply it in a variety of settings. Programs like the Port of Long Beach Academy of Global Logistics serve as an excellent model for career-focused education that provides exciting opportunities for students to become well-versed in career-building skills before they enter the workforce, along with providing them essential networking opportunities and opportunities to develop related workforce skills such as public speaking and project development.

GIS-focused education lends itself extraordinarily well to these kinds of project and applied learning environments. When educators are able to effectively incorporate GIS into everyday learning, it creates opportunities to practice spatial reasoning, and allows students to make real-time connections between abstract concepts being taught in class and their real-world applications. The data-driven aspects of GIS allow students to practice reading maps, analyzing data, visualizing data, and thinking critically when examining information in real-world scenarios. When students are able to practice these skills across a variety of classrooms (math,

science, history) and using a wide variety of data and data systems, these spatial reasoning skills become even more natural, and contribute to the building blocks of truly innovative and creative thinking. These skills are key to building up a resilient and independent workforce that will be on the forefront of data driven work in future generations.

Looking ahead to future projects and building comprehensive programming that incorporates elements of rigorous teacher training on GIS and developing project or problem-based curriculums would be a promising area of future development. In particular, programming that incorporates career exploration and exposure for young people in conjunction with larger applied-learning projects would be an exciting and innovative way of developing GIS programming that prepares students for a variety of careers and contributes to developing a career-focused and data-literate future workforce. Creating opportunities for students to interface with a variety of professionals that use GIS in their work currently will allow students to visualize themselves in this work even more easily, humanizing the field and demystifying the use of data and science in careers that may look very different from what they imagine data science to be. Other expansions to a GIS workshop day could include more large-scale programs that last for an entire semester or year. These longer programs would give students and teachers more time becoming familiar with GIS, and the variety of subjects that it can be applied in. Throughout these programs, as a network of support, teachers can be given community resources and use Esri as a GIS hub. Not only is Esri known for their GIS software, but their platform also provides an array of resources and materials should teachers need assistance in curriculum planning. Programs exploring the feasibility of semester or year-long GIS programs that work across subjects and use GIS as a key tool for final projects may yield exciting results, ideally increasing student interest and pursuit of GIS programs in higher education, and increased competency in maps and data visualization, regardless of future career choices.

References

1. Camera, L. *U.S. Students Are Really Bad at Geography.* US News & World Report, 2015. https://www.usnews.com/news/articles/2015/10/16/us-students-are-terrible-at-geography. Accessed July 28, 2020.
2. Kerski, J. GIS in K-12. *xyHT Magazine, December 10th, 2018.* https://www.xyht.com/spatial-itgis/gis-in-K-12/
3. KQED. *Five Compelling Reasons for Teaching Spatial Reasoning to Young Children.* https://www.kqed.org/mindshift/47301/five-compelling-reasons-to-teach-spatial-reasoning-to-young-children. Accessed December 3, 2020.
4. Lee, C. Worksheet Usage, Reading Achievement, Classes' Lack of Readiness, and Science Achievement: A Cross-Country Comparison. *International Journal of Education in Mathematics, Science and Technology,* 2018, 2: 2. https://doi.org/10.18404/ijemst.38331.
5. Webinar: Investigations in Transportation: Partnering Industry Professionals and Elementary Teachers in a STEM Unit of Study. *National Institute for Transportation and Communities.* https://nitc.trec.pdx.edu/events/professional-development/webinar-investigations-transportation-partnering-industry. Accessed July 21, 2020.
6. Rainey, K., M. Dancy, R. Mickelson, E. Stearns, and S. Moller. Race and Gender Differences in How Sense of Belonging Influences Decisions to Major in STEM. *International Journal of STEM Education* 2018, 5: 1. https://doi.org/10.1186/s40594-018-0115-6.
7. *Women in STEM: 2017 Update*. https://www.commerce.gov/news/fact-sheets/2017/11/women-stem-2017-update. U.S. Department of Commerce, 2017.
8. Racial Diversity and Discrimination in the U.S. STEM Workforce. *Pew Research Center's Social & Demographic Trends Project,* 2018. https://www.pewsocialtrends.org/2018/01/09/blacks-in-stem-jobs-are-especially-concerned-about-diversity-and-discrimination-in-the-workplace/.
9. Transportation Occupations. *Deloitte.* https://datausa.io/profile/soc/transportation-occupations. Accessed January 21, 2021.
10. James, S.M., and C.B. Marrett. Innovations in STEM Education. *Journal of the Washington Academy of Sciences,* 2011. 97(3): 55–66.
11. Xie, Y., and D. Reider. Integration of Innovative Technologies for Enhancing Students' Motivation for Science Learning and Career. *Journal of Science Education and Technology,* 2014. 23(3): 370–80.
12. Preininger, A.M. Embedded Mathematics in Chemistry: A Case Study of Students' Attitudes and Mastery. *Journal of Science Education and Technology,* 2017. 26(1): 58–69. https://doi.org/10.1007/s10956-016-9651-3.
13. National Transportation Career Pathways Initiative Final Project Report. *California State University Long Beach Research Foundation,* 2019. https://www.nntw.org/wp-content/uploads/2020/04/NTCPI-Year-Two-Report-final.pdf

14. Children's Environmental Health Initiative. GIS Analyst (Limited - Term). Geospatial Jobs Clearing House, 2021. https://web.archive.org/web/20210421180108/https://www.gjc.org/cgi-bin/showjob.pl?id=1618247069 Accessed April 21st, 2021
15. Rails to Trails. Conservancy GIS Analyst. Geospatial Jobs Clearing House, 2021. https://web.archive.org/web/20210421181035/https://www.gjc.org/cgi-bin/showjob.pl?id=1616703969 Accessed April 21st, 2021
16. Morton. GIS Developer. Geospatial Jobs Clearing House, 2021. https://web.archive.org/web/20210421180751/https://www.gjc.org/cgi-bin/showjob.pl?id=1617823519 Accessed April 21st, 2021
17. County of Orange. Surveyor II. GovernmentJobs, 2021. https://web.archive.org/web/20210421212346/https://agency.governmentjobs.com/oc/job_bulletin.cfm?jobID=2969201 Accessed April 21st, 2021
18. City of Wentzville. Civil Engineer. GovernmentJobs, 2021. https://web.archive.org/web/20210419183802/https://agency.governmentjobs.com/wentzville/default.cfm?action=jobbulletin&JobID=3040700 Accessed April 21st, 2021
19. 15 Best Restaurants to Try in Highland Park. *Eater LA*, 2019. https://la.eater.com/maps/best-highland-park-los-angeles-california-resaturants-places-to-eat.
20. Learning to Think Spatially. *Committee on support for Thinking Spatially: The Incorporation of Geographic Information Science Across the K-12 curriculum,* 2006. https://www.nap.edu/read/11019/chapter/1
21. Rød, J.K., W. Larsen, and E. Nilsen. Learning Geography with GIS: Integrating GIS into Upper Secondary School Geography Curricula. *Norwegian Journal of Geography,* 2010. 64(1): 21–35. https://doi.org/10.1080/00291950903561250.
22. Bednarz, S. W. Geographic Information Systems: A Tool to Support Geography and Environmental Education? *GeoJournal,* 2004. 60(2): 191–99.
23. Teach with GIS. https://learn.arcgis.com/en/educators/. Accessed November 5, 2020.
24. *GIS and Geospatial Technology*. UCLA Continuing Education Online. https://www.uclaextension.edu/digital-technology/gis-geographic-information-systems/certificate/gis-and-geospatial-technology. Accessed October 1, 2020.
25. *Geographic Information Systems Certificate of Achievement < San Bernardino Valley College.* https://catalog.valleycollege.edu/degree-certificate-program-index/geographic-information-systems-gis/geographic-information-systems-certificate-achievement/#requirementstext. Accessed October 1, 2020.
26. *Geographic Information Sciences.* https://cla.csulb.edu/departments/geography/geographic-information-sciences/. Accessed October 1, 2020.
27. *The Port of Long Beach Academy of Global Logistics at Cabrillo (AGL).* https://lbcabrillo.schoolloop.com/cabrilloacademyofbusiness. Accessed November 5, 2020.

28. *2020 AAPA Excellence in Communication Awards.* https://aapa.files.cms-plus.com/AwardsCompetitionMaterials/2020CommunicationsAwards/CommunityEducationOutreach/POLB-Community-Education%20Outreach-Academy%20of%20Global%20Logistics.pdf. Accessed January 13th, 2021.

29. Neubert, J. *10 Ways Competition Enhances learning.* https://www.competitionsciences.org/2016/07/04/10-ways-competitions-enhance-learning/. Accessed January 13th, 2021.

30. National Academy of Engineering. *Changing the Conversation: Messages for Improving Public Understanding of Engineering.* Washington, DC: The National Academies Press, 2008. https://doi.org/10.17226/12187.

31. Rhodes, M., S.J. Leslie, K.M. Yee, and K. Saunders. Subtle Linguistic Cues Increase Girls' Engagement in Science. *Psychological Science*, 2019. 30(3):455-466. https://doi.org/10.1177/0956797618823670

32. Tom R. Baker, Sarah Battersby, Sarah W. Bednarz, Alec M. Bodzin, Bob Kolvoord, Steven Moore, Diana Sinton & David Uttal (2015) A Research Agenda for Geospatial Technologies and Learning, Journal of Geography, 114:3, 118-130, https://doi.org/10.1080/00221341.2014.950684