An Assessment of Geospatial Technology Integration in K–12 Education

Zachary M. Osborne, Saskia L. van de Gevel, Montana A. Eck, and Margaret Sugg

Abstract
K–12 geography education is often grouped with other subjects, limiting student exposure to geospatial technology and geographic inquiry. We explored the implementation of geospatial technology in North Carolina K–12 schools through a forty-four-question survey. Educators shared their teaching methods, geospatial technology integration, and professional development experience. Survey responses were statistically tested for multiple subpopulations, including rural, urban, and state-sponsored schools. Results suggest a lack of geography state standards, professional development opportunities, and classroom utilization of most geospatial technologies, which contribute to the deficiencies of geographic inquiry–based learning in North Carolina. Future North Carolina K–12 initiatives require changes to curriculum standards, professional training, and classroom resources.

Key Words: *geography education, professional development, geospatial technology, K–12 geography standards*

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Introduction

According to the 2014 National Assessment of Educational Progress (NAEP), only 27% of eighth-grade students in the United States were proficient in geography (United States Department of Education, Institute of Education Sciences, and National Center for Education Statistics 2014). Proficiency rates were similar to 1994 survey results, highlighting a lack of progress in geographic proficiency among students. K–12 schools teach geography as a subdiscipline of the broader discipline of social studies banner that includes history, civics, and economics (United States Government Accountability Office [USGAO] 2014). As a result, time spent on geographic concepts is often lost to other disciplines within the social studies curriculum. Across the United States, more than 50% of eighth-grade social studies educators spent less than 10% of their instruction time on geography (Bednarz, Heffron, and Solem 2014). Many geography educators do not have an education in geography and feel they are ill equipped to teach geographic knowledge in the classroom (Schell, Roth, and Mohan 2013; Hinde 2014). Research points to teachers feeling unprepared to teach the subject because of a shortage of professional development experiences focused on teaching K–12 geographic concepts and skills (Schell et al. 2013).

States vary greatly in their emphasis on geographic education in K–12 classrooms (McClure and Zadrozny 2015). North Carolina is one of six states that does not require K–12 coursework in geography (McClure and Zadrozny 2015). The state is among twelve that do not require a geography course to finish middle school and thirteen that do not require a geography course to finish high school in the United States (McClure and Zadrozny 2015). In North Carolina, geography only represents four of the twenty-six social studies standards in fourth grade. History, economics and financial literacy, civics and government, and culture are the other twenty-two standards (North Carolina Public Schools 2013). Geography is only three of the twenty-eight social studies standards in eighth grade. The lack of focus on geographic concepts and methods severely limits exposure to geographic inquiry–based learning. Therefore, North Carolina finds itself on the low end of geography exposure compared to other U.S. states.

Geographic inquiry–based learning is crucial to the development of basic critical thinking and spatial analytical skills and capabilities (Favier and Schee 2012; American Association of Geographers [AAG] 2015) and is often communicated through geospatial technologies. Geospatial technology is at the center of current growth in the professional market presence of geography (USGAO 2014). The interdisciplinary nature of spatial skills gained from geospatial technologies can overlap geography with scientific literacy and science, technology, engineering, and math (STEM) fields (Goldstein and Alibrandi 2013; AAG 2018; Xuan et al. 2019). Unfortunately, current North Carolina social studies standards do not mention geospatial technology (North Carolina Public Schools 2013).

Teaching the various types of geospatial technologies requires an understanding of concepts and methods. The principles of technological, pedagogical, and content knowledge (TPACK) methods suggest that what an educator teaches and how the educator teaches the material are the basis of technology integration in the classroom (Mishra and Koehler 2006; Hong and Stonier 2015). TPACK methods assist in the development of geographic inquiry–based learning skills through innovative geospatial technology integration techniques and provide a deeper understanding of core spatial concepts (Doering et al. 2014). The lack of TPACK methods in K–12 social studies classrooms is concerning because it is useful in classroom technology integration (Hong and Stonier 2015). Currently a need for research on TPACK-based learning technologies on local scales exists (Doering et al. 2014), such as the utilization of various types of geospatial technologies in state K–12 classrooms.

The USGAO (2014) interviewed K–12 officials in Arkansas, California, Florida, and Virginia about the limitations regarding the use of geospatial technology in the classroom. Many state officials in the study indicated that there were not enough resources in their respective states to upgrade instruction to reflect a more hands-on, technical skills approach. Some educators noted that time severely limited the planning of interactive exercises (USGAO 2014). While the USGAO (2014) highlighted feedback from officials in four states with widely varying degrees of emphasis on K–12 geography education, we specifically focus on North Carolina, one of six states without a required geography course at the K–12 level. As such, the state is an example of one with poor exposure to geospatial technology and geographic inquiry–based learning.

This North Carolina case study compares the implementation status of various types of geospatial representation and technology across K–12 classrooms. Our work builds on previous studies by investigating the differences among educator subpopulations by analyzing survey results using qualitative and quantitative methods (McClurg and Buss 2007). Our research questions were as follows:

1. What are the various geospatial representations and technologies integrated into K–12 classrooms throughout North Carolina and what factors potentially influence the implementation of these technologies throughout the state?
2. How do past education and professional development experience reflect classroom instruction of geographic inquiry–based learning in North Carolina, and are there limitations to further professional development in geospatial technology?

To answer these research questions, we analyzed the experience of surveyed teachers to various types of geospatial representations and technologies, educators' perspective on the perceived learning difficulty, and the amount of classroom integration among all educators and specific subpopulations. Additionally, we compared the academic knowledge of surveyed teachers to various types of geospatial technology, their perspective on the perceived learning difficulty, and the amount of classroom integration. We also evaluated professional development experience to compare effectiveness in geospatial technology implementation throughout North Carolina K–12 schools.

Context

Geospatial technologies are now a part of our daily lives and are a crucial growing sector within the discipline of geography (DiBiase et al. 2010; AAG 2018). People use global positioning systems (GPS), cell-phone tracking, and mobile applications that integrate geospatial technology through widespread tools and practices. The integration of geospatial technology is abundant outside of the classroom, with applied use in national security, city planning, and natural disaster response. According to the United States Department of Labor, employment of geographers will rise 29% from 2012 to 2022 (USGAO 2014), with many of these positions utilizing geospatial technology. However, many educators still teach geography using textbooks and PowerPoint presentations. These strategies fail to capture the basic concepts of the rapidly emerging geospatial technologies field (Schell et al. 2013).

Including geographic inquiry–based learning in the classroom leads to a deeper understanding of knowledge across all subjects (National Research Council [U.S.] 2006). Geospatial technologies are solidly rooted in STEM subjects because of its inquiry-based approach and concepts of space (Hagevik 2011). Examples of K–12 geospatial projects in STEM education include exploring a local ecosystem through the transfer of GPS data into grids or calculating speed and distance across multiple scales through data obtained from GPS units (Hagevik 2011). Past research also highlights the effectiveness of utilizing geospatial technologies in a wide range of K–12 subjects outside of what is traditionally defined as STEM education, including music (Purves 2017), history (Hammond 2014), and language arts (Hagevik 2011). Geospatial tools greatly influence how students and educators think about geospatial information. These tools facilitate data collection, visualization of spatial relationships, and filtering or querying of geospatial data, all activities that students can use to examine spatial data and patterns (Baker et al. 2015).

Professional development needs to be connected with the implementation of geospatial technologies in the K–12 classroom (Baker et al. 2015). Professional development activities are crucial for educators to understand geospatial technologies. For teachers without prior experience through their collegiate education, participation in professional development can be useful in providing learning opportunities. Professional development experiences can lead to profound positive changes for teaching geography in the classroom (McClurg and Buss 2007; Doering et al. 2014; Tabor and Harrington 2014; Collins and Mitchell 2019; Mitchell, Roy, Fritch, and Wood 2018). However, there is a lack of professional development opportunities in the United States for educators who want to learn more about geospatial technology (Bednarz, Heffron, and Huynh 2013). Past research suggests that professional development is a critical issue that needs improvement to enhance the nation's capacity for geographic inquiry (Bednarz, Heffron, and Huynh 2013; Collins and Mitchell 2019).

This study compares the level of knowledge and implementation of a variety of geospatial representations (hard copy maps, charts, and graphs) and technologies (GPS, geographic information systems [GIS], remote sensing [RS], and digital mapping) to understand which geospatial tools are currently being used in the classroom (Baker et al. 2015). Additionally, we explore past education and professional development experiences to explore the state of the use of geospatial technology in K–12 classrooms in North Carolina. The general utilization of GIS or other specific types of geospatial technology have been studied in different areas of the United States (Patterson 2007; Baker, Palmer, and Kerski 2009; Favier and Schee 2012; Hong 2014). Our research compares the implementation of various geography tools and geospatial technologies in K–12 classrooms and examines the influence of classroom integration on a statewide scale. We evaluated the results to recommend changes within the North Carolina K–12 education system toward a greater emphasis on geospatial technology and geographic inquiry–based learning.

Method

The role of geospatial technology and geographic inquiry–based learning in K–12 classrooms in North Carolina was investigated by conducting a convenience sample using a forty-four-question survey through the SurveyMonkey online website. North Carolina K–12 educators answered questions about their teaching methods, geospatial technology integration, and professional development experiences. We integrated academic training, background exposure to the subject of geography and its technologies, and socioeconomic influences on their classroom methods in the survey. The survey included twenty-seven multiple-choice questions, six fill-in-the-blank responses, and eleven Likert-scale questions. We divided the forty-four questions into five sections: Personal Background, Class Information, Teaching Background, Experiences In and Out of the Classroom, and Professional Development.

The Personal Background section included educator demographic information and their highest degree earned. The Class Information section included school and student demographics. The Teaching Background portion of the survey asked for information concerning teacher preparedness for the subject of geography, past exposure to geospatial technologies in their own education, and personal beliefs in the role of geospatial technology in the classroom. The Experiences In and Out of the Classroom section asked respondents to define which geospatial representations and technologies they had personal experience with, which of the technologies they implemented in their course, and which potential limiting factors of geospatial technology implementation were relevant to their classroom. Professional Development was the final portion of our survey; educators answered questions concerning professional development experiences.

We developed five-point Likert scales for eleven of the questions, with the maximum level response corresponding to a five. For example, answers to "How prepared do you feel to teach your class at the assigned level?" range from "not prepared" (1) to "very prepared" (5), and answers to "To what degree are the following items limiting factors to the implementation of geospatial technologies in you class?" range from "least limiting" (1) to "most limiting" (5).

We conducted nonparametric statistical tests (e.g., Chi-square tests) to determine statistically significant differences between subpopulations in the perceived limitations of geospatial technologies in the classroom. Subpopulations of respondents included urban counties (eight counties with a population over 200,000: Wake, Mecklenburg, Guilford, Forsyth, Cumberland, Durham, Buncombe, and New Hanover), and rural counties (ninety-two counties with a population of fewer than 200,000). We considered counties as urban based on criteria by the Southern Appalachian Vitality Index (SAVI 2018). State-sponsored schools (public and magnet) and non-state-sponsored schools (private and charter) were also compared statistically.

The survey was administered to the North Carolina Geographic Alliance Listserv of approximately 600 teachers and a Facebook group page that included 176 North Carolina K–12 educators. We recorded the respondent's age, gender, location, and survey completion date in each response. Survey responses with one or more sections left unanswered were not included in our analysis. We used sixty-six completed surveys for qualitative and quantitative analyses. Details regarding educators' teaching methods and use of geospatial technology in the classroom were included in the survey results, as well as their thoughts and opinions concerning geospatial technology.

Results

Completed surveys ($n = 66$) came from thirty-one North Carolina counties (Figure 1), with the most

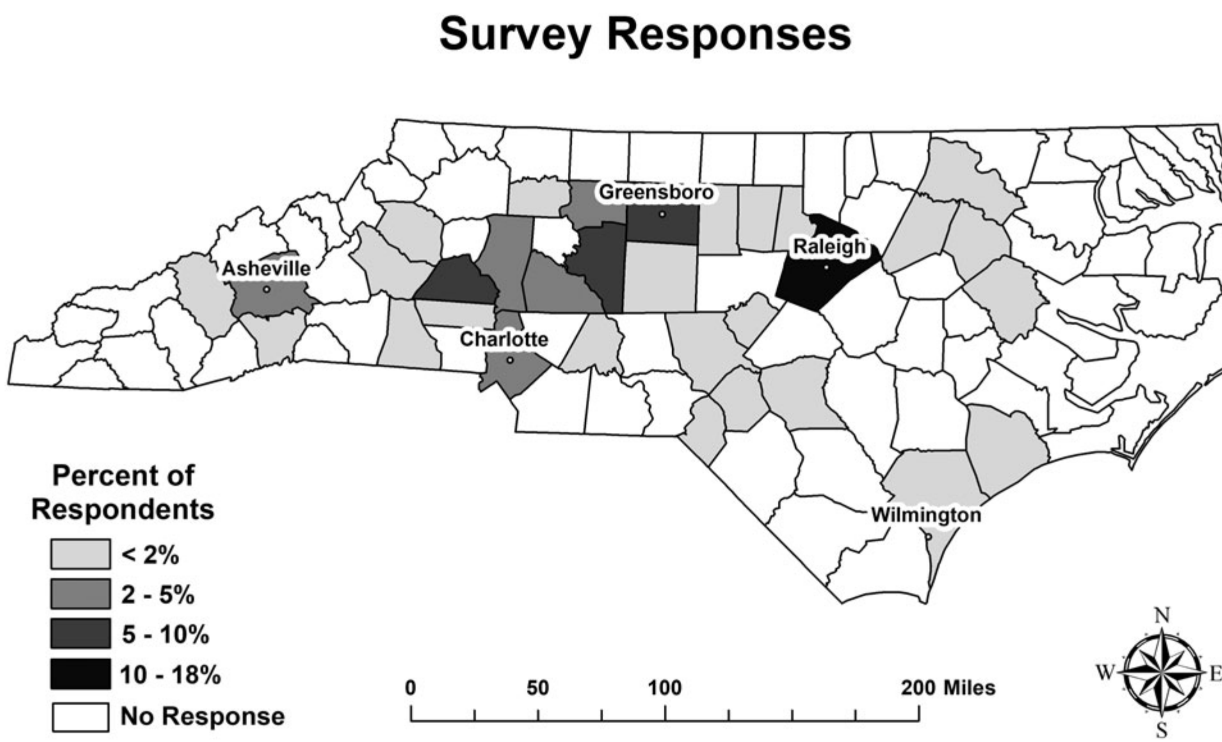

Figure 1. The number of complete surveys by county within North Carolina, USA ($n = 66$). Counties with a higher amount of survey responses are indicated by darker shades of gray. Many of the counties reporting the greatest amount of responses include major urban centers throughout the state.

surveys completed in urban areas. Most of our respondents were white, were female, and had fewer than ten years of teaching experience. More than half of surveyed educators earned a master's degree in education (Table 1). The majority of the respondents taught middle school, followed by high school and elementary school. Over 84% of educators taught in public schools, while 7.6% taught in private schools and 7.6% in charter schools. For the purpose of this study, we grouped charter schools with private schools as non-state-sponsored schools, which resulted in 15.2% of all respondents grouped as representatives of non-state-sponsored schools.

Our results support previous research that characterizes K–12 students in North Carolina as among the least exposed in the country to geographic inquiry–based learning (McClure and Zadrozny 2015). Approximately 97% of surveyed educators believed that educators did not easily understand geospatial technology (Table 1). Nearly six out of ten (59.1%) respondents personally believed that geospatial technology is not necessary to enhance the education of their subject. However, 63% believed that problem-based activities are more effective than textbook-based exercises.

While GIS, RS, GPS, and digital globes represent the four core geospatial technologies (Baker et al. 2015), hard-copy maps were the most reported type of geospatial representation in the K–12 classroom, and educators frequently used Google Earth as a geospatial technology (Figure 2). Mixed results emerged when geospatial technologies used in the classroom were compared in relation to the cost and availability of each product. Google Earth and OpenStreetMap are both free and accessible programs available with a computer. While 78% of surveyed educators reported integrating Google Earth into the classroom, only 9% reported doing the same with OpenStreetMap. Educators incorporated cost-effective technologies, including satellite imagery, Google Earth, and 360° photos/videos, into the classroom at higher rates than non-cost-effective technologies. Educators used costlier technologies, such as 3-D printing and virtual reality glasses/headsets, less frequently in the classroom.

Teacher familiarity with products reveals why some technologies are integrated more into classrooms than others. Nearly 94% of our respondents reported a familiarity with Google Earth, and 79% of those familiar with Google Earth used the software in their classes. Only 16.7% of respondents reported a familiarity with OpenStreetMap, with the majority of them (54.5%) implementing it in their classroom. Google Earth and OpenStreetMap serve as examples of how exposure leads toward integration in the classroom.

Table 1. North Carolina educators responded to a request for a demographic and geographic inquiry survey. While the vast majority of participants reported receiving education in teaching their subject, the majority also state that geospatial technology is not necessary for the education of subject material. More than 90% of educators reported that geospatial technologies are not easily understood by teachers.

Surveyed North Carolina K–12 Educators ($n = 66$)			
Average age of educator 44.5		Ethnicity	
Gender		White	95.5%
Male	16.7%	African American	3.0%
Female	83.3%	Hispanic	1.5%
Years teaching subject		School type	
Fewer than 10	51.5%	Public	84.8%
10 to 20	27.3%	Private	7.6%
More than 20	21.2%	Charter	7.6%
Highest degree		School level	
Bachelor's	37.8%	Elementary	24.2%
Master's	56.1%	Middle	48.5%
PhD/EdD	4.5%	High	27.3%
Was teaching your subject part of your college education?		Is geospatial technology necessary for student learning of subject material?	
Yes	78.8%	Yes	30.3%
No	21.2%	No	69.7%
Are problem-based exercises more effective than textbook-based exercises?		Are geospatial technologies easily understood by teachers?	
Yes	63.6%	Yes	3.0%
No	36.4%	No	97.0%

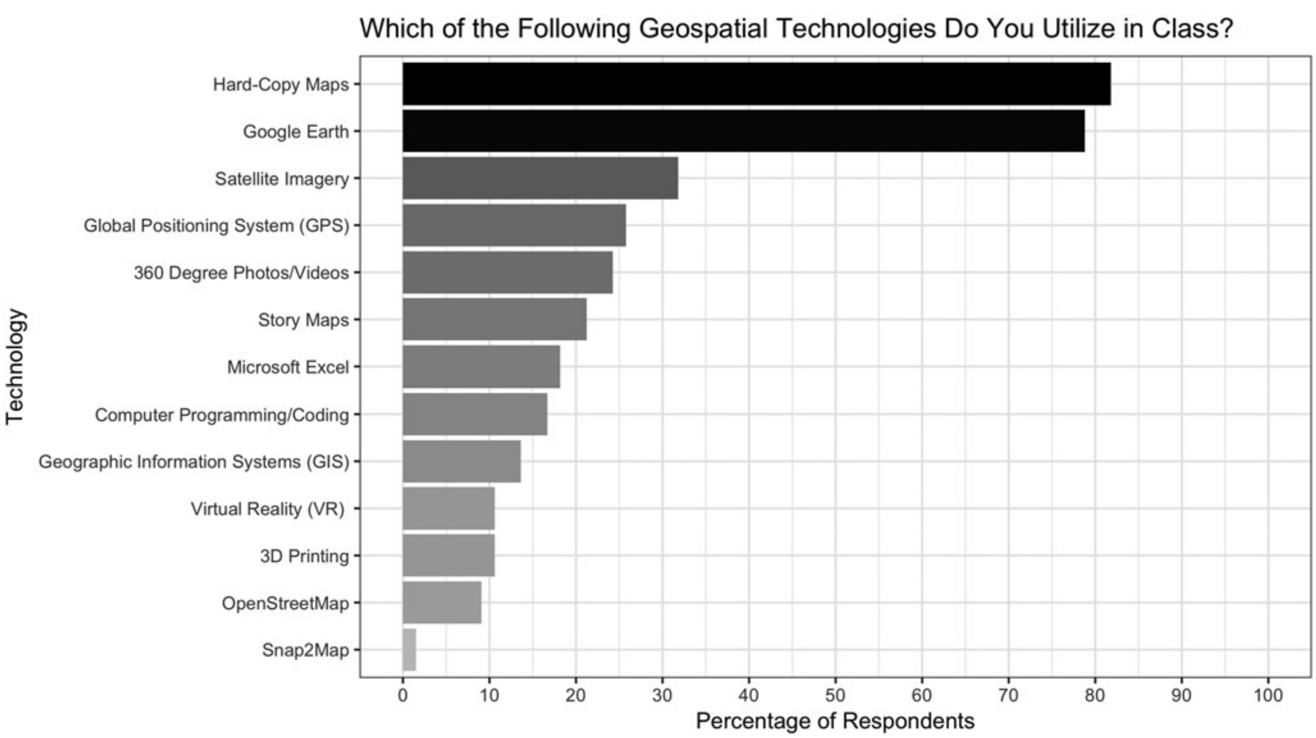

Figure 2. The integration level for each geospatial technology among educators. Easily accessible, low-cost technology options represent the highest overall percentages of integration in the classroom. Despite the accessibility and low cost, OpenStreetMap had among the lowest percentages of integration.

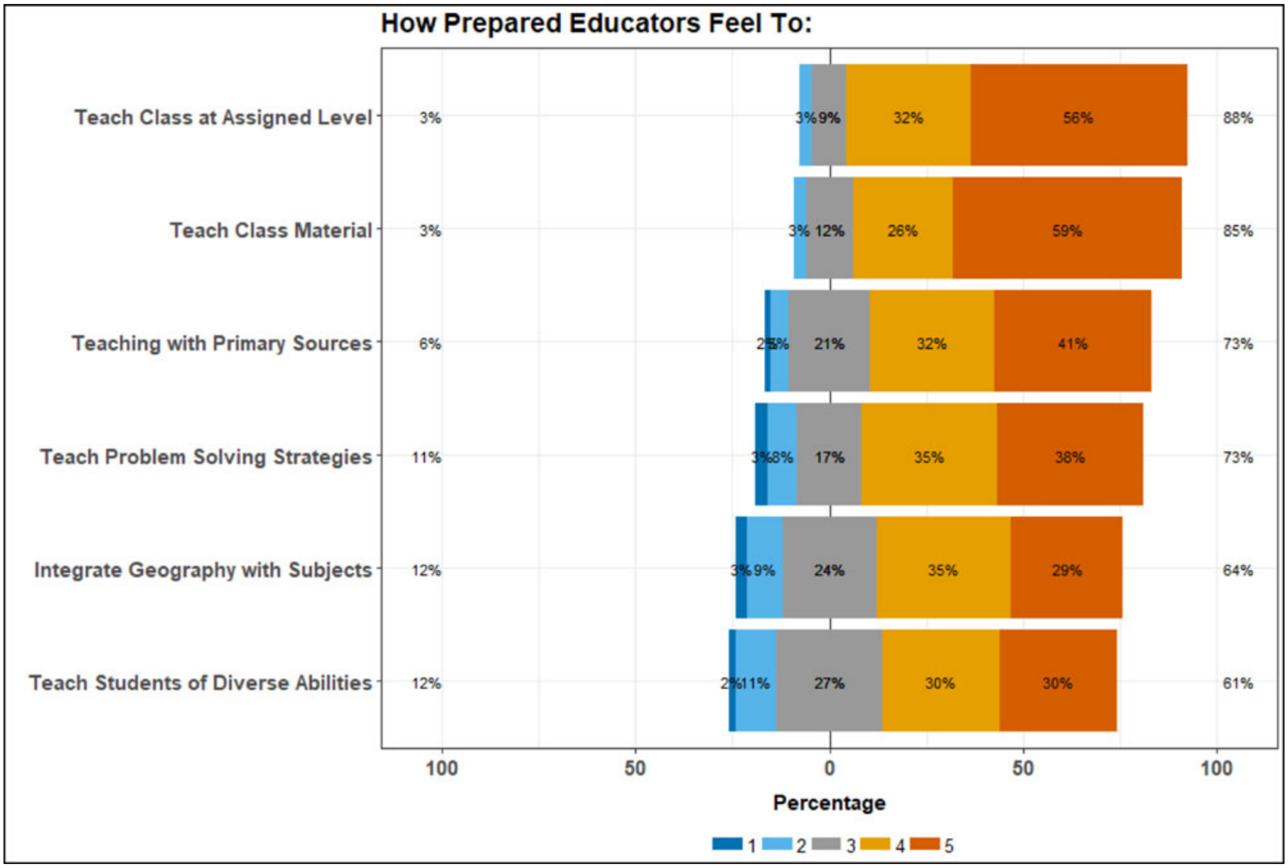

Figure 3. Educator responses to level of past preparation experiences, with responses of (5) indicating "very prepared" and responses of (1) indicating "not prepared." Respondents indicated a high level of knowledge in teaching class material at the appropriate level. Educators also reported a strong preparedness in integrating geography with other subjects. (Color figure available online.)

More than 85% of educators felt moderately to highly prepared to integrate geography into other subjects, and 95% of respondents felt that they were moderately to highly prepared to teach their course material (Figure 3). Nearly 79% stated that teaching their subject was part of their academic training (Table 1). Approximately 90% of educators responded that they were moderately to highly prepared to teach their course with primary sources (documents and raw data) and to teach problem-solving strategies in the classroom. However, fewer than one-third of educators asked their students to make a map or use GIS for data analysis in the classroom. Only 22% of the educators had enrolled in prior collegiate coursework in GIS.

More than 90% of respondents believed that geospatial technologies were not easy to integrate into the classroom. The most reported limiting factors to geospatial technology integration were the availability of the technology, the cost of the technology, and the unfamiliarity with the technology (Figure 4). The main challenge to the implementation of geospatial technology in the classroom is the lack of educator exposure.

We analyzed non-parametric chi-square tests to determine potential differences in survey results between geospatial integration in subpopulations based on school type and urban/rural schools (data not shown). Responses regarding the limitations of the integration of geospatial technology were compared between educators who represented state-sponsored (public and magnet) schools and respondents who represented non-state-sponsored (private and charter) schools. State-sponsored school respondents had a statistically significant higher concern about the absence of training than non-state-sponsored schools ($p = .03$). A statistically significant difference also existed in the familiarity with and potential adaptability of geospatial technology between urban and rural counties. Urban county respondents reported being more familiar with geospatial technology than those in rural counties ($p = .02$). A statistically significant difference also emerged in the

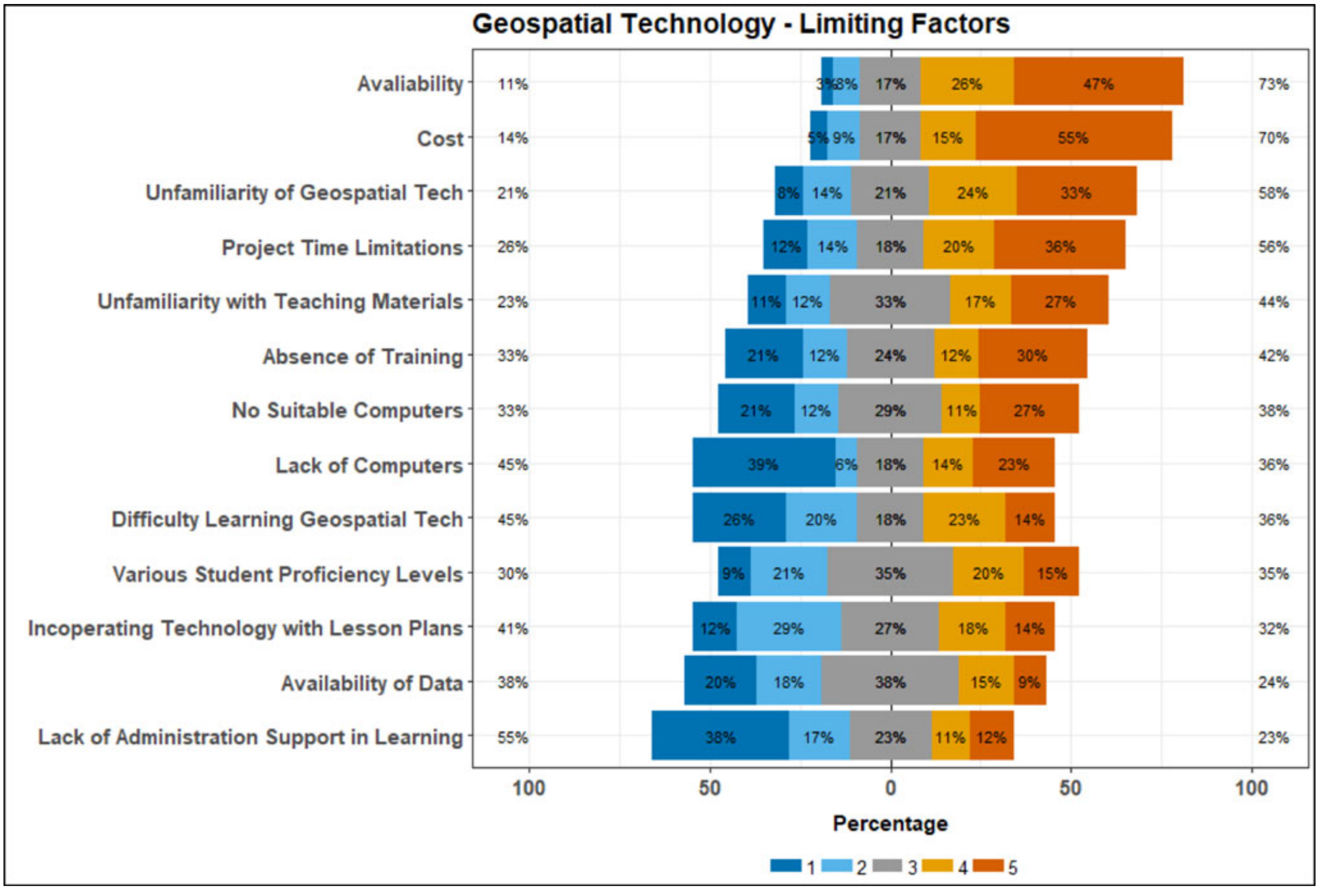

Figure 4. Survey responses to potential limiting factors in geospatial technology integration in North Carolina K–12 classrooms, with responses of (5) indicating "most limiting factors" and responses of (1) signifying "least limiting factors." The largest limiting factors to the utilization of geospatial technology, according to our survey participants, were the availability, cost, and unfamiliarity with the technologies. (Color figure available online.)

number of computers suitable for geospatial technology in rural schools, as respondents in rural counties perceived the number of suitable computers as a larger detriment to geospatial technology integration than participants in urban counties ($p = .07$).

More than 65% of educators reported insufficient professional development opportunities within North Carolina. Professional development experiences placed the largest emphasis on studies concerning subject material and state standards of the subject material (Figure 5). More than 80% of our respondents noted that professional development experiences placed a moderate or heavy emphasis on enhancing subject standards. State curriculum frameworks, standards, and/or guidelines affected how 84.8% of educators taught their classes. More than half of surveyed educators responded that district curriculum frameworks, standards, and/or guidelines influenced their classroom instruction, 39.4% responded national education subject standards, 34.8% reported state test results, and 15.2% responded that district tests influenced course material.

Discussion and Implications

The survey results demonstrate several challenges to the integration of geospatial technologies in North Carolina's K–12 schools. Surprisingly, more than 50% of the educators believed that geospatial technology was not necessary to enhance geography education in North Carolina schools. Educators did not use geospatial technologies in the majority of North Carolina K–12 classrooms. More than 90% of educators did not understand geospatial technology well and therefore thought that geospatial technology was not easy to integrate into the classroom. Another limiting factor to the implementation of geospatial technologies was the cost and availability of the various technologies. The results regarding technology availability support similar findings to the USGAO (2014), namely that the lack of resources is a hindrance to

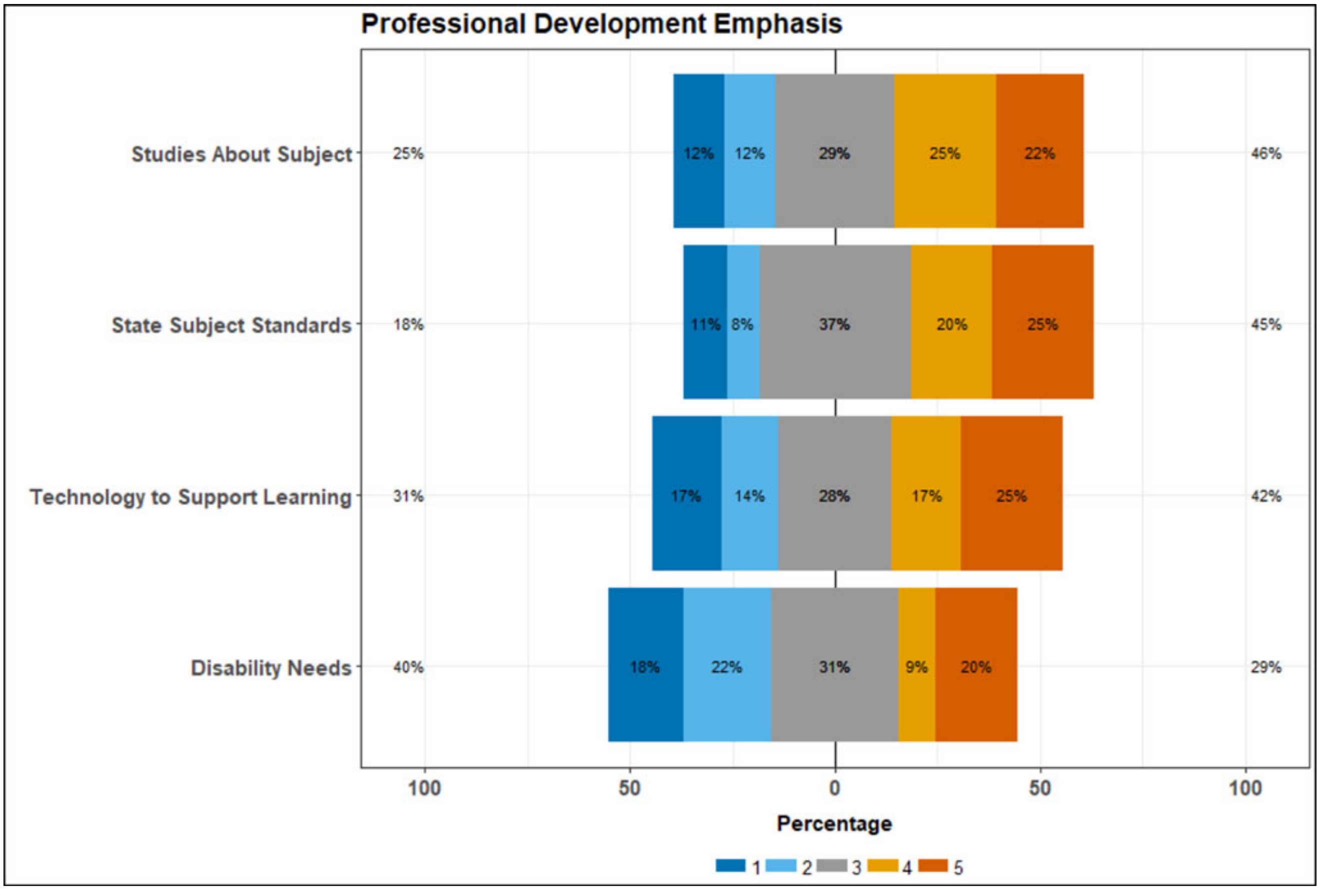

Figure 5. The current state of K–12 professional development emphasis in North Carolina, with a response of (5) indicating "heavy importance" and a response of (1) signifying "nonexistent." The largest focus areas were on studies about the subject and state standards of the subject. (Color figure available online.)

the implementation of interactive exercises. Educators are more likely to implement geospatial technologies in the classroom if they personally possess experience in the technologies (Schell et al. 2013). Because teachers are not exposed to various types of geospatial technology during their education in college, the lack of integration affects the role these technologies play in K–12 education (Shin, Milson, and Smith 2016).

Hard-copy maps and Google Earth were the most utilized geospatial representation and technology in the classroom. Spatial skills can be improved by using both hard-copy maps and digital programs (Collins 2018), which suggests a long-term presence of hard-copy maps in the classroom alongside potential growth in the presence of online mapping with geospatial technology. Hard-copy maps and digital technology are complementary to each other (Collins 2018). New technologies can innovate classroom settings, but the importance of hard-copy maps should not be undervalued. Educators were familiar with Google Earth as a free and easy-to-navigate tool. However, other low-cost and easily accessible geospatial technologies, such as OpenStreetMap, were not as widely integrated into the classroom. We need to expose educators to cost-effective technologies through publicity, professional/education opportunities for teachers, and targeted outreach. Even with the large difference in the K–12 educators' familiarity with Google Earth and OpenStreetMap, more than 50% of educators familiar with these respective technologies used them in the classroom.

Training educators on accessible, cost-effective geospatial technologies through professional development experiences is crucial to the integration of geospatial technology in the K–12 classroom and student learning. Educators could allow students to explore more contemporary resources, such as volunteered geographic information, web 2.0, and the "Internet of things," that do not require training (Wells and Lewis 2006; Bull, Hammond, and Ferster 2008; Curtis 2019). The rise in the public popularity of programable world maps (e.g., Google maps, Bing Maps) and virtual globes (e.g., Google Earth, NASA's WorldWind) highlights the opportunity for

K–12 education to leverage this analytical technology, which can encourage important spatial reasoning for more sophisticated geospatial technologies at the collegiate level (e.g., GIS and RS). Student exposure to technologies generates learning experiences, which in a geospatial context can provide real-world opportunities to explore and make sense of new knowledge (Curtis 2019).

Statistical differences among subpopulations from the chi-square results provide further evidence of the disparity between professional training for geospatial technology integration and the need for innovative solutions to address this lack of equity in geospatial education resources. More targeted professional development experiences should focus on rural counties and state-sponsored schools where respondents are less familiar and have fewer resources for geospatial technology than urban and non-state-sponsored schools.

The lack of educators' exposure to geospatial technologies in their prior collegiate coursework hinders geospatial education at the K–12 level. Our results support past research (Bednarz and Audet 1999), which suggests that the lack of integration in teacher education programs could affect the role of geospatial technology in the classroom. To address geospatial education deficiencies adequately, integration of geographic inquiry–based learning and geospatial technology must occur in a collegiate setting, with the training of future educators before they start their teaching careers (Collins and Mitchell 2019). Many North Carolina educators attend universities in the state of North Carolina through programs such as North Carolina Teaching Fellows (Henry, Bastian, and Smith 2012). Geography professors in North Carolina, and across the country, should integrate more geospatial technologies into their geography introductory courses and not rely on geospatial technology–specific courses (e.g., GIS, geospatial technologies, and RS) to teach spatial reasoning concepts.

Most educators reported insufficient professional development opportunities within North Carolina. Our results support past findings of the lack of professional development opportunities to train teachers in the use of geospatial technologies (Bednarz, Heffron, and Huynh 2013) and geography education (Schell et al. 2013). Exposing educators to these technologies during professional development opportunities will likely lead to further integration of concepts and practices in the classroom (Schell et al. 2013). A greater importance should be placed on low-cost, easily-accessible geospatial technology (e.g., web 2.0, virtual globes) through professional development opportunities. Professional development experiences should focus on the interactive capabilities of geospatial technology as it relates to course material and state standards. Operating professional development experiences in this manner would expand opportunities to a greater number of educators in the state and lead to greater utilization of geospatial technologies and geographic inquiry–based learning in North Carolina's K–12 classrooms.

Professional development opportunities in geospatial technologies, however, do not necessarily lead to changes in teacher practice in the classroom if they are applied to course material (Trautmann and MaKinster 2010; Rubino-Hare et al. 2016). Rubino-Hare et al. (2016) noted that many teachers who initially implement methods learned through professional development experiences eventually retreat back into their old teaching methods. This may be because of the lack of continuing technical support for teachers who utilize the technology in the classroom (Rubino-Hare et al. 2016). Many educators find it difficult to connect geospatial processes from professional development into specific curriculum goals (Trautmann and MaKinster 2010), and student assessment in courses may be structured in a way that limits the potential of new technological enhancements (Rubino-Hare et al. 2016). Recent advances, such as TPACK-based professional development experiences, may translate into better implementation of geospatial technology, particularly in North Carolina (Hong and Stonier 2015). Hong (2014) found that including teachers at deeper levels in professional development, through integrating educators into lesson development, further aids in the potential to implement technology. Educators need long-term support to sustain innovative approaches gained through professional development (Höhnle et al. 2016). We need more analysis and surveys targeted at geospatial literacy to pinpoint the most effective formats for successful professional development and learning experiences.

State and district standards greatly affect how educators teach their subject, and respondents suggest a heavy emphasis on subject standards in professional development activities. We recommend changes to North Carolina's current social studies standards to reflect a greater emphasis on geographic inquiry–based learning that highlights the interdisciplinary nature and utilization of geospatial technologies in subjects throughout the curriculum. Modifying current standards to include geographic inquiry–based learning experiences through geospatial representation and technology could lead to a greater amount of interactive classroom exercises and product generation outputs, two aspects of classroom methods utilized by the majority of our respondents. This research revealed that most educators believe that geospatial technology is not necessary to enhance the education of their subject. However, geospatial technology provides fresh avenues for product generation through problem-solving exercises with primary sources individually and in small groups. Past research highlights that the implementation of these methods through geospatial technology enhances geographic inquiry–-based learning (Metoyer and Bednarz 2017). Geographic inquiry–based learning aids in the ability to capitalize on knowledge of current subject information through interactive exercises with geospatial technology.

Conclusion

By investigating the use of different geographic technologies throughout North Carolina, a state with less emphasis on the integration of geographic inquiry–based learning than most other states, our understanding of major challenges associated within local-level, K–12 geospatial technology implementation was enhanced.

Our research indicates that educators' exposure to geospatial technology is associated with utilization. A high emphasis on cost-efficient professional training, which focuses on free or low-cost geospatial technology, enhances the potential for the implementation of geographic inquiry–based learning exercises. This is especially true in rural areas and non-state-sponsored schools, where statistical tests reported less familiarity with geospatial technologies and a higher concern for the absence of current training opportunities among rural school populations.

Incorporating TPACK methods through the utilization of geospatial technology expands growth in spatial reasoning and critical thinking (Doering et al. 2014), and we recommend introducing these methods and practices in future North Carolina K–12 curriculum standards, teacher education programs, and professional development experiences. Despite the current perceived level of difficulty of geospatial technologies, educators show that they are willing to learn new methods. The state of North Carolina should take advantage of educators' curiosity and passion to learn to enhance the K–12 classroom experience. North Carolina schools and organizations should support innovative professional development that focuses on subject trends and implementation methods of geospatial technology. Professional development programs could leverage freely accessible services available on the web (virtual globes, etc.). Integrating geospatial technology into North Carolina K–12 classrooms allows educators and students to expand geographic inquiry–based knowledge through interactive, innovative problem-solving techniques based in tools that are common in our daily lives (AAG 2018). Implementing geographic inquiry–based learning through geospatial technology at the K–12 level develops student critical thinking skills, spatial awareness, and local to global connections at an interdisciplinary level. Geospatial thinking deserves to be a priority in classrooms in the North Carolina education system and across the country.

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