BRIDGING THE GEOSPATIAL EDUCATION-WORKFORCE DIVIDE: A CASE STUDY ON HOW HIGHER EDUCATION CAN ADDRESS THE EMERGING GEOSPATIAL DRIVERS AND TRENDS OF THE INTELLIGENT WEB MAPPING ERA

by

Wendy Rose Stout

Liberty University

A Dissertation Presented in Partial Fulfillment

Of the Requirements for the Degree

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APPROVED BY:

Carol Ann Gillespie, Ph.D. Committee Chair

Matthew Ozolnieks, Ph.D. Committee Member

ABSTRACT

The purpose of this exploratory collective case study is to discover how geospatial education can meet the geospatial workforce needs of the Commonwealth of Virginia, in the emerging intelligent web mapping era. Geospatial education uses geographic information systems (GIS) to enable student learning by increasing in-depth spatial analysis and meaning using geotechnology tools (Baker & White, 2003). Bandura's (1977) self-efficacy theory and geography concept of spatial thinking form an integrated theoretical framework of spatial cognition for this study. Data collection included in-depth interviews of twelve geospatial stakeholders, documentation collection, and supporting Q methodology to determine the viewpoints of a total of 41 geospatial stakeholders. Q methodology is a type of data collection that when used as a qualitative method utilizes sorting by the participant to determine their preferences. Data analysis strategies included cross-case synthesis, direct interpretation, generalizations, and a correlation matrix to show similarities in participants' preferences. The results revealed four collaborative perceptions of the stakeholders, forming four themes of social education, technology early adoption, data collaboration, and urban fundamentals. Four strategies were identified for higher education to prepare students for the emerging geospatial workforce trends. These strategies are to teach fundamentals, develop agile faculty and curriculum, use an interdisciplinary approach, and collaborate. These strategies reflect the perceptions of stakeholders in this study on how higher education can meet the emerging drivers and trends of the geospatial workforce.

Keywords: geospatial education, geographic information systems, intelligent web mapping, competency, workforce preparedness

Dedication

I dedicate my dissertation work to my amazing and loving husband, Jeff Stout. Your strength and support are the foundation for every accomplishment of my life. You have encouraged me to continue my education and supported me as I completed my undergraduate, graduate, and now Ph.D. throughout our marriage. You have shown me unwavering love and patience through this educational journey. Jeff, you lead our family in faithfulness to Christ and ground me in truth each day to keep my focus on the things that truly matter. John: 15:5 "*I am the vine; you are the branches. Whoever abides in me and I in him, he it is that bears much fruit, for apart from me you can do nothing.*"

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Advanced Technology Education Program (ATE)

Architecture Construction and Engineering (ACE)

Artificial Intelligence (AI)

Association of American Geographers (AAG)

Application User Interface (API)

Augmented Reality (AU)

Autonomous Underwater Vehicle (AUV)

Building Automation System (BAS)

Body of Knowledge (BoK)

Career and Technical Education (CTE)

Coastal National Elevation Database (CoNED)

Connected Autonomous Vehicles (CAV)

Countries Geospatial Readiness Index (CGRI)

Department of Labor (DOL)

Department of Labor Employment and Training Administration (DOLETA)

Developing a Curriculum (DACUM)

Federal Aviation Administration (FAA)

Federal Emergency Management Agency (FEMA)

Federal Geographic Data Committee (FGDC)

Geospatial Industry Outlook and Readiness Index Report (GeoBuiz)

Geographic Information Science and Technology (GIS&T)

Geographic Information Systems (GIS)

Geographic Information Systems Certificate Institute (GISCI)

Geographic Technology Competency Model (GTCM)

Geospatial Artificial Intelligence (GAI)

Geospatial Data Act (GDA)

Geospatial Intelligence (GEOINT)

GIS as a Service (GaaS)

Global Positioning Systems (GPS)

High Growth Job Training Initiative (HGJTI)

High-Altitude Pseudo Satellites (HAPS)

Historically Black Colleges and University (HBCU)

Indoor Positioning System (IPS)

Infrastructure as a Service (IaaS)

Institutional Review Board (IRB)

Internet of Things (IoT)

Light Detection and Ranging (LiDAR)

Massive Open Online Course (MOOC)

National Aeronautics and Space Administration (NASA)

National Geospatial Technology Center of Excellence (GeoTech Center)

National Research Council (NRC)

National Science Foundation (NSF)

National Spatial Data Infrastructure (NSDI)

National States Geographic Information Council (NSGIC)

National Emergency Number Association (NENA)

Next Generation 9-1-1 (NG9-1-1)

Occupational Information Network (O*NET)

Open Geospatial Consortium (OGC)

Place Location Knowledge (PLK)

Planning District Commission (PDC)

Platform as a Service (PaaS)

Public Participation GIS (PPGIS)

Public Safety Answering Point (PSAP)

Radio Frequency Identification (RFID)

Real-Time Kinematic (RTK)

Rich Internet Applications (RIA)

Service-Oriented Architecture (SOA)

Software as a Service (SaaS)

Spatial Data Infrastructure (SDI)

Synthetic Aperture Radar (inSAR)

Three Dimensional (3D)

United Nations Agenda for Sustainable Development (UN-ASD)

United Nations Committee of Experts on Global Geographic Information Systems (UN-GGIM)

United Nations Integrated Geospatial Information Framework (UN-IGIF)

University Consortium for Geographic Information Science (UCGIS)

United States Geologic Survey (USGS)

University of Southern Mississippi (USM)

Unmanned Aerial Vehicles (UAV)

Urban and Regional Information Systems Association (URISA)

Virginia Geographic Information Network (VGIN)

Virginia Space Grant Consortium (VSGC)

Virtual Reality (VR)

Volunteered Geographic Information (VGI)

World Geospatial Industry Council (WGIC)

CHAPTER ONE: INTRODUCTION

Overview

Geographic information systems (GIS) has evolved at a rapid pace over the past twenty years. Technological advances such as ubiquitous high-speed internet connectivity, high-performance cloud computing, advanced sensor platforms and networks, and autonomous smart machines combined with geospatial analytics have created technology disruption in the geospatial industry (UN-GGIM, 2020). Geospatial education provides knowledge and understanding of geographic information systems to students and must evolve to include current and emerging trends in the geospatial workforce. The geospatial education-workforce divide is characterized by inertia in GIS education programs slowing adaptation to emerging drivers and trends of the geospatial workforce. This study focused on the perceptions of GIS stakeholders concerning the emerging geospatial technology trends of the intelligent web mapping era that the geospatial education curriculum needs to address to meet the demands of the geospatial workforce. This section of this study provides a background to the problem, situation to self, the problem statement, purpose statement, significance of the study, and research questions that are addressed in the study. Additionally, the definitions relevant to the study will be provided. Finally, a chapter summary will conclude this section.

Background

Geographic Information Systems (GIS) began primarily in the field of geography and evolved as a technology that was useful in both industry and modern educational practice in many countries across the world (Andjelkovic & Pavlovic, 2015). Web GIS has been developed as a form of GIS that encompasses the same data, functionality, and interface capability of desktop GIS but is done on the web (Veenendaal et al., 2017). This study will reference web mapping which is a more general approach that includes all web mapping functions for users and applications. Geospatial education is a field that is focused on teaching GIS (desktop and web). The GIS workforce often shapes GIS education. This is true not only in geospatial education but also in any field of education. Barton and Kirsch (1990) reported that it is difficult to find consensus on what skills will be needed tomorrow or even in what direction change will occur, but that educational institutions must prepare students to adapt to changing requirements.

Historical

The term geographic information systems indicates a shift that occurred from maps as static images manually created by pens and planimeters with the primary purpose of navigation to computerized mapping with spatial analysis capabilities (Davis & Schultz, 1990). GIS originally began in the 1960s with the publication of "A Geographic Information System for Regional Planning" detailing the first operational computerized GIS system (Tomlinson, 1969). Tomlinson, often called the “Father of GIS,” created a computer system that allowed for data layers, measurement, and digitizing capabilities in the field of Forestry. The 1970s represent the beginning years of modern GIS with the advent of commercial computer mapping primarily for computer-assisted cartography and remote sensing (Davis & Schultz, 1990). These two fields were worlds apart with research on vector data and raster data happening separately with virtually no crossover (Berry, 2013). By the mid-1980s, the GIS community realized that both could be beneficial based on the specific use case.

The decade of the 1980s featured spatial database management due to changes in data formats available and expansion of the computer mapping environment (Mark et al., 1996). Commercial GIS software vendors entered the market and began organizing attribute data using databases. They also improved digitizing equipment and methods (Berry, 2013). Early GIS research during this time recognized the primary importance of drawings (maps) and statistics (analysis) which are both vital to current geospatial technology (Seyhan, 1995).

Map analysis and modeling characterized a shift to prescriptive analysis in the 1990s. Spatial analysis in this decade differed from the spatial statistics of the 1980s because it involved context-based processing. A new comprehensive theory of map analysis explored spatial relationships that allowed for both qualitative and quantitative processing and opened GIS to many new applications that supported decision-making. Since geography explores the knowledge and understanding of spatial phenomena, processes, and meanings from a local to a global perspective, GIS found a home in this discipline in the 1990s (National Research Council, 2006). Geography education began to emerge as a way to analyze these interconnections by teaching maps as a form of spatial representation in the field of geography (NCGE, 2003; see also Bunch & Lloyd, 2006; Kim et al., 2012; Liben, 2007). GIS supports the goals of geography education by establishing a spatial framework for interdisciplinary interconnections and by educating geographers on why these relationships are significant (Bednarz, 2004; Kemp & Goodchild, 1991).

Similarly, web mapping would be introduced as a new concept in the 1990s. In the early 1990s, during the Web 1.0 era, web mapping consisted of static Hyper Text Markup Language (HTML) and hyperlinked images (Veenendaal et al., 2017). Later in the mid-1990s, dynamic HTML content, Common Gateway Interface (CGI), Java, and Active X provided a way for the user to interact with the web map and the launch of online atlases (Veenendaal et al., 2017). By the end of the 1990s, web map services that were constructed using service-oriented architecture (SOA) were published on the web. The first dynamic web mapping capabilities became available with MapQuest (Matney et al., 2019).

Not surprisingly, many geographers were less than enthusiastic about the integration of geospatial technology as a tool in geography education for many years (Schuurman, 2000). The influence of the military and GIS use of Descartes' Cartesian system of coordinate geometry to represent lines, points, and polygons caused some geographers to view GIS as positivist and empirical (Kumar et al., 2019; Pickles, 2006). This fueled a debate between users of GIS who valued the potential of this technology in the discipline of geography and geographers who were focused on the social aspects of geography (Pickles, 1995; see also Schuurman, 2000; Sheppard, 1993). GIS practitioners of the time defended GIS as a valuable tool and argued that research should be done on the limitations of GIS instead of attacking the technology (Goodchild, 1991; Openshaw, 1991). Although most geographers have now accepted the value of GIS in the field, there is still a concern among social geographers that GIS can be used as a tool to harm communities by exclusion and by ignoring social relations, traditions, values, and practices (Reid, 2019).

Several key milestones in the GIS community that created the foundations for geospatial education are notable. The *National Centre for Geographic Information and Analysis GIS Core* (1990) document established an early blueprint for university GIS education (Baker et al., 2012). The *First National Conference on the Educational Applications of GIS (EdGIS) Conference Report* (1994) publication laid the foundation that eventually led to the establishment of the professional international GIS community (Baker et al., 2012). The 2000s became a decade of spatial reasoning and dialog that blossomed once geographers realized that social geography and GIS technology did not have to be exclusive. Early GIS education research was conducted and published in *The Special Issue of the Journal of Geography* (National Council for Geographic Education, 2003).

One significant development of geospatial education was a national survey instrument to examine teacher professional development needs for implementation of desktop GIS (Baker et al., 2009). This was the first survey on a national scale to provide valuable insights into the challenges and benefits of GIS education. The findings of this study indicate that real-world experiences using GIS can increase student motivation (Baker et al., 2009). Baker et al., (2012) issued a renewed call for research in the form of a foundational literature review that revealed that GIS as a field was greatly under-researched.

Hardware issues, lack of training, and software incompetency are often hindrances to higher education instruction of emerging geospatial technologies (Liu et al., 2011). Web mapping is one way to overcome the hindrances in geospatial education. Several significant occurrences in 2005 fueled the growth of web mapping (Tsou, 2005). Natural disasters in 2005 (South Asia Tsunami and Hurricane Katrina) created a global demand for rapid response GIS mapping for emergency management. Additionally, free satellite imagery and wireless location-based services became available. These factors created the perfect conditions for the explosion of web mapping along with internet technology advances that led to more accessibility and faster response times on the web (Tsou, 2005). Multimedia mapping became a significant focus in the geospatial industry between 2010-2016. Anyone with the Internet could participate in web mapping and become an amateur mapper (Haklay, 2010). Standard web applications became accessible such as Google Maps which incorporated collaborative digital globe capabilities to give users an immersive three-dimensional experience (Plewe, 2007). Web mapping has been found to increase performance-based knowledge with the use of comments, tags, and shares (Thom et al., 2016). In addressing emerging multi-media and web mapping geospatial technology, Câmara et al. (2009) identified sensor networks, mobile devices, and remote sensing as important geospatial workforce trends of the time. These trends were precursors to the intelligent web mapping trends of today.

The intelligent web mapping era which began around 2016 cannot be defined by any particular trend or technology, but it refers to the way that the web is used to extract knowledge from data to provide intelligent context for web applications and GIS users (Veenendaal et al., 2017). Digital infrastructure drives what is referred to as digital transformation (Hausberg et al., 2019). In the field of geospatial technology as in multiple other industries, digital transformation often refers to technological changes and their impacts on society, communication, and business processes (Gimpel & Röglinger, 2015; Jung, 2017). The development of rich internet applications (RIA), cloud computing, and crowdsourcing have made web mapping a global way to interact and engage in a geographic context (Tsou, 2011). Geospatial digital transformations that utilize this type of intelligent web mapping will drive changes in geospatial education.

The continued expansion and development of intelligent web mapping technologies have emerged as influential drivers and trends to the geospatial workforce (Matney et al., 2019; UN-GGIM, 2020). Intelligent web mapping technologies bring to light new concerns such as governance, data interoperability, data ethics, cybersecurity, privatization of data, privacy, jurisdiction, and marginalization of groups. Building standards and collaboration between stakeholder groups is a crucial challenge for this era (UN-GGIM, 2020). There is a need for more research investigating the implications and applications of the intelligent web mapping era on geospatial education and the workforce.

Theoretical

Bandura referred to the phrase “generative capability” which relates to the theoretical concept of self-efficacy and the relational measure of a person’s self-confidence in their abilities in any given field (Bandura, 1977, p. 37). The theory of self-efficacy as described by Bandura (1977) is important in gauging students' confidence in applying geospatial competency learned in university GIS courses to real-world success in the geospatial workforce. The geographical concept of spatial and geospatial thinking provided an additional context for this study (Kim & Bednarz, 2013; see also Jant et al., 2019; Jo et al., 2016). Spatial thinking involves cognitive skills, concepts of space, and reasoning processes to solve problems (Gersmehl & Gersmehl, 2007; see also Golledge et al., 2008; Janelle & Goodchild, 2009, NRC, 2006). The relationship between GIS and students' critical thinking, spatial reasoning, and problem-solving is foundational and necessary to prepare students to effectively use geospatial technology in the workforce (Kim & Bednarz, 2013). Spatial thinking and self-efficacy formed an integrated theoretical framework of spatial cognition for this study.

Social

Higher education is becoming more interested in preparing students to enter geospatial careers by offering GIS degree and certificate programs at all levels including associate, bachelor, master's, and doctoral degrees (Kerski, 2008). Other providers of geospatial education include high school pipeline programs such as the Geospatial Semester in Virginia (Kolvoord et al., 2019). Additionally, software providers, colleges, and employers often provide workshops and GIS short courses (Bodin, 2018). The positive outlook for GIS job opportunities in government, engineering, utilities, environmental, military, agriculture, transportation, mining, healthcare, archaeology, and many other careers is a strong motivation for GIS education to prepare students to succeed in the workforce.

Geospatial educator perceptions are well documented in the literature. Several qualitative studies review the effectiveness of GIS-based projects and participatory GIS in geospatial education (Demirci et al., 2013; Rambaldi, 2005; Sinha et al., 2016). Those who teach geospatial education have very positive views of the results of their implementation efforts for preparing students for success (Baker et al., 2009). Equity in the geospatial workforce is an important social issue. A need for addressing social issues led to a call for more gender equity in the field of GIS by women geographers in the early 2000s (Kwan, 2002; McLafferty, 2005; Reid, 2019). The lack of women represented in the GIS field and the marginalization of women and people of color in the GIS industry were noted as potential research gaps on the social implications of how people, space, and environment are represented in GIS (Harris, 1996).

Situation to Self

I have a unique perspective having served as the professor preparing students for GIS employment and the geospatial professional interviewing recent graduates for GIS positions. I have risen through the ranks of the GIS workforce, starting as a GIS technician working for the Federal Emergency Management Agency (FEMA) serving during Hurricane Katrina, later serving as a GIS education specialist for the National Aeronautics and Space Administration (NASA) Virginia Space Grant Consortium (VSGC), and finally leading as Geospatial Program Manager for the Commonwealth of Virginia. For 10 months, I performed the duties of the State Geospatial Coordinator which is the highest state government GIS position in the Commonwealth of Virginia. This role provides GIS strategic planning for the Commonwealth of Virginia. In my primary role for the Commonwealth, in addition to managing the statewide Orthophotography and Light Detection and Ranging (LiDAR) data collection for Virginia, I served as a liaison for all GIS stakeholders across the state including GIS educators. Additionally, I previously served as Director of Spatial Analysis for an institution of higher education. I am currently employed as an Instructional Technologist and Adjunct GIS Professor in the Virginia community college system.

Part of my motivation for this study is that I wanted to research if what Virginia GIS stakeholders perceived as necessary knowledge for success in the workforce correlated well with the GIS curriculum professors in higher education are teaching to their students. A social constructivism framework that seeks to "understand the world" in which the participants' work was used in this study (Creswell, 2013, p. 24). For this study, ontological assumptions allowed the participants to describe and reflect on their experiences by sharing their own perceptions (Creswell & Poth, 2018). This study was conducted as an exploratory collective case study to report the different perspectives or realities of various GIS stakeholders in Virginia including educators, private businesses, and local and state government GIS professionals. Axiological assumptions for the study were that the worldviews and lived experiences of the geospatial stakeholders will be different and unique. Epistemological assumptions for the study were grounded in my experiences in geospatial education and the geospatial workforce. Because my background shapes my interpretation, it was my intent as a researcher to conduct an exploratory collective case study that sought to understand a specific issue from multiple perspectives.

Problem Statement

The problem is that the geospatial curriculum has not been updated to reflect the skills needed to meet the emerging intelligent web mapping era trends of the geospatial workforce (Kumar et al., 2019; Perez-delHoyo et al., 2020; Rickles & Ellul, 2017). The U.S. Department of Labor projects a 19 percent growth in jobs utilizing geospatial technology between 2016 and 2026 (Bureau of Labor Statistics, 2017). Multiple institutions of higher education in the Commonwealth of Virginia and across the nation provide geospatial education to students.

Students may pursue GIS coursework as a major or minor, a certificate program, or a GIS course as part of their curriculum in many other majors. Each of these routes may lead to employment in the field of GIS. There is evidence-based research that geospatial education can have the positive effect of helping learners prepare for employment by utilizing emerging geospatial technology (Perez-delHoyo et al., 2020).

The United Nations Committee of Experts on Global Geographic Information Management (UN-GGIM) has provided guidance to all nations on significant developments and trends in the “Future Trends in Geospatial Information Management Report: the five to ten-year vision” (2020). Several studies consider the effectiveness of geospatial education pedagogy and the value of framing curriculum design using the Department of Labor Employment and Training Administration (DOLETA) Geographic Technology Competency Model (GTCM) in higher education (DiBiase et al., 2007, 2010; see also Ahlqvist, 2011; Prager & Plewe, 2009; Van Orshoven, 2009). There is a lack of direct research to evaluate the perception of geospatial stakeholders on emerging workforce geospatial skills/competencies that have evolved after the last update of the DOLETA GTCM.

Purpose Statement

The purpose of this exploratory collective case study is to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia. Geospatial education is generally defined as using spatial technology to enable student learning by increasing in-depth analysis and meaning using geotechnology tools throughout this research (Baker & White, 2003). The theories guiding this study are Bandura’s (1977) self-efficacy theory and the geographical concept of spatial thinking (McGee, 1979) which form the integrated theoretical framework of spatial cognition for this study. Spatial cognition is required for any type of geospatial context and GIS enhances the investigation, analysis, and evaluation of data (Hamilton, 2016).

Significance of the Study

The theoretical framework of spatial cognition is important to GIS education. The theoretical significance of this study is that spatial cognition can be positively impacted by utilizing digital GIS technologies in the classroom (Gersmehl & Gersmehl, 2007; see also Bearman et al., 2015; Collins, 2017; Golledge et al., 2008; Kim & Bednarz, 2013). This study adds to the body of literature by providing stakeholder perceptions of how spatial cognition can be taught in geospatial education and how spatial cognition is valuable to the geospatial workforce.

The empirical significance of the study is that there is a gap in the empirical, peer-reviewed literature examining how geospatial education can meet the geospatial workforce trends in the context of the intelligent web mapping era. Geospatial web mapping technology developments are identified by researchers including Hall and Tirooanis (2012), Peng and Tsou (2003), Tsou (2005, 2011), and Plewe (2007). These researchers identified significant GIS geospatial workforce trends and categorized them by era (as cited in Veenendaal et al., 2017). Veenendaal et al. (2017) reviewed these significant trends and introduced a new category – the intelligent web mapping era. Matney (2020) studied the evolution of the intelligent web mapping era further by identifying several emerging intelligent mapping era trends. The UN-GGIM Future Trends Report validates many of the trends identified by previous researchers including Veendendaal et al. (2017) and Matney (2019) and reiterates that intelligent web mapping era competencies are essential to the global geospatial workforce. Geospatial drivers and trends listed in the UN-GGIM Future Trends Report were used in this study as the primary source for identifying emerging geospatial trends. A search of research on Google Scholar found no previous studies to date have utilized the UN-GGIM Future Trends Report (2020) to investigate emerging geospatial workforce trends or to connect emerging trends to the geospatial education curriculum. The current research adds to existing knowledge by gaining stakeholder perception of the geospatial drivers and trends listed in the UN-GGIM Future Trends Report which is the most comprehensive, current, and authoritative source available that examines intelligent web mapping trends.

While many studies have addressed some of these technologies or future geospatial trends, only two previous studies (Matney, 2019; Veenendaal et al., 2017) were identified in Google Scholar to have previously examined the geospatial workforce trends in the context of the intelligent web mapping era. Although Matney acknowledged that geospatial education was needed to support competency for these trends, neither Matney (2019) nor Veenendaal et al. (2017) addressed how geospatial education can support preparing students for the workplace in the intelligent web mapping era. The current research extends existing knowledge to include the role of geospatial education in preparing students for the emerging workforce trends of the intelligent web mapping era.

From the standpoint of practical significance to the study and practical application, addressing how well universities are meeting emerging intelligent web mapping era geospatial workforce needs has real-world value. If the gaps identified in this study are addressed by universities, then the outcome will benefit students and employers. If institutions adjust their curriculum or course/degree offerings to address gaps that are identified, the quality of geospatial education will be increased which will help students to be better prepared to succeed in the geospatial workforce. This will lessen the time and cost of on-the-job training that is needed by geospatial employers to get their new employees to the level of skill needed for the job. Also, one other practical significance of this study would be potential competency additions in the future updates of the DOLETA GTCM or occupation additions to the DOLETA O*NET.

Research Questions

This exploratory collective case study sought to examine the different perspectives or realities of GIS stakeholders to determine how effectively geospatial technology education meets emerging intelligent web mapping geospatial workforce needs in the Commonwealth of Virginia. The theoretical framework of this study is spatial cognition which integrates self-efficacy and spatial thinking. These theories provide a theoretical framework for the research questions.

The following central research question guide the research in this study:

RQ: How do educators, state government mangers, local government managers, and industry stakeholders perceive the emerging geospatial drivers and trends that are impacting the geospatial workplace? Virginia employers in the public and private sector, as well as non-profits and local and state government, offer entry-level positions in the field of Geographic Information Systems. Clear insight is needed into geospatial stakeholder perspectives on the emerging intelligent web mapping era geospatial technology demands of the workforce. Research on geospatial education related to workforce needs has remained insufficiently explored for the past 20 years of study (Wallertin et al., 2015). Johnson and Sullivan (2010) emphasize the importance of addressing the geospatial workforce needs to strengthen higher education geospatial education and advise academia to seek coordination with industry on geospatial curriculum and programs.

SQ1: How do geospatial stakeholders describe emerging technological advancements in the geospatial workforce? Morrison and Lowther (2002) note that traditional higher education is far behind industry in adopting new technologies. Many new technological advancements are impacting the geospatial workforce including the availability of high-speed internet capability, cloud computing, the geospatial internet of things (IoT), digital twins, intelligent transport systems, edge computing, artificial intelligence, machine learning, and visualization technologies (Pourabbas, 2014; UN-GGIM, 2020).

SQ2: How do geospatial stakeholders perceive the rise of new data sources and analytical methods in the geospatial workforce? Researchers have reported a rise in new data sources and analytical methods. Big data, data mining, and data analytics are evolving at a rapid pace with many applications in the industry (Chen et al., 2015). New sources of data including big data, linked data, social media data, and crowdsourced data are being collected on a staggering scale. Remote sensing data such as LiDAR, imagery, satellite, UAV, and bathymetry data are becoming more accessible to geospatial education and the workforce (UN-GGIM, 2020).

SQ3: How do geospatial stakeholders describe the evolution of user requirements? The rapid changes in the geospatial industry create challenges in training the workforce of tomorrow in the skills and capabilities needed in effective organizations (UG-GGIM, 2020). Education and advocacy on all levels are critical to preparing students to meet the geospatial challenges of societal concerns such as climate change, renewable energy, and developing a sustainable future. Meeting the user experience expectations and the demand for open data and real-time information provision connected to intelligent web mapping is a significant requirement for smart city solutions in urban environments.

SQ4: How does the industry structural shift in the geospatial workforce impact geospatial stakeholders? Private and non-government sector geospatial companies have facilitated a shift from physical to digital geospatial platforms. This sector is expected to drive the emerging technologies of the next decade to produce data-driven solutions to business problems (Green, 2020). Open Geospatial Science is facilitating education, collaboration, and best practices. Enabling diversity offers great opportunities for the future of geospatial education to all students. The perspectives of both educators and geospatial industry professionals are needed to foster collaboration and cooperation in the geospatial community to develop a geospatial education curriculum that will benefit students and addresses workforce needs.

SQ5: How do geospatial stakeholders characterize the geospatial legislation environment? The United Nations Future Trends report advocates for national strategic planning. The United States published a strategic plan addressing the geospatial interests of the nation but there is much more to be done concerning standards, ethics, interoperability, accessibility, and governance. Advances have greatly outpaced geospatial legislation (UG-GGIM, 2020). Geospatial stakeholder perceptions of the importance of geospatial legislation can provide insight into the values of the collective geospatial industry.

Higher education must facilitate practices that align with current and future geospatial workforce requirements. Geospatial education programs should embrace the implementation of teaching pedagogy that meets the needs of employers (DiBiase et al., 2010; Johnson and Sullivan, 2010). If universities are using the DOELTA GTCM to guide their instruction they may be missing emerging intelligent web mapping era trends such as geospatial artificial intelligence and virtual reality (Matney, 2019). It is important to document the perceptions of Virginia stakeholders on how the geospatial curriculum should be updated to reflect the skills needed to meet the emerging trends of the geospatial workforce.

Definitions

1. *Geographic Information Systems* - system for storing and analyzing geospatial information using technology (Kerski, 2003)
2. *Geospatial Education* - using spatial technology to enable student learning by increasing in-depth analysis and meaning using geotechnology tools (Baker & White, 2003)
3. *Intelligent Web Mapping* - the web is used to extract knowledge from data to provide intelligent context for web applications and GIS users (Veenendaal et al., 2017)
4. *Q-methodology* - a research method used to study participant viewpoints (McKeown & Thomas, 2013)

Summary

Supporting the geospatial education curriculum in preparing students to succeed in the geospatial workforce is critical (Wallentin et al., 2015). The problem is that the geospatial curriculum has not been updated to reflect the skills needed to meet the emerging intelligent web mapping era trends of the geospatial workforce (Kumar et al., 2019; Perez-delHoyo et al., 2020; Rickles & Ellul, 2017). The purpose of this exploratory collective case study is to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia.

CHAPTER TWO: LITERATURE REVIEW

Overview

The problem is that the geospatial curriculum has not been updated to reflect the skills needed to meet the emerging intelligent web mapping era trends of the geospatial workforce. This is thoroughly reviewed by investigating literature that identifies relevant research in the field of GIS, geospatial education, and web mapping trends. The purpose of this exploratory collective case study is to discover how geospatial education can meet emerging geospatial workforce needs in the Commonwealth of Virginia. More importantly, a better understanding of emerging intelligent web mapping geospatial trends is needed to prepare entry-level geospatial graduates for the geospatial workforce. Chapter Two is a review of the literature regarding how the evolving needs of the geospatial workforce have been addressed in the field of geospatial education. The review of literature is divided into five parts: a theoretical framework, spatial cognition research, preparing students for the geospatial workforce, government influence, and emerging geospatial drivers and trends in the workforce. The literature review is based on these topics which emerged as common themes in the research.

Theoretical Framework

The theoretical framework is important to qualitative research because it provides a theoretical basis for the research study (Creswell, 2013). The current exploratory collective case study specifically employs self-efficacy theory and the geographical concept of spatial thinking as an integrated model to form the theoretical framework of spatial cognition. This framework is foundational in the investigation of stakeholder perceptions of emerging geospatial workforce needs and to what extent the current geospatial education curriculum meets those needs.

The concept of spatial cognition has been part of geography for many years, but the lack of a clear definition makes it problematic for researchers (Ishikawa, 2016; NRC, 2006). Additionally, the National Research Council (NCR) (2006) notes that several terms are often used interchangeably without distinction such as spatial ability, spatial thinking, spatial intelligence, and spatial cognition. These terms, although similar, should not be confused and are surprisingly complex.

Spatial thinking is part of everyday life. It is considered universal and explains how students comprehend spatial information and use it to make decisions (Jo & Bednarz, 2009). It applies to both academia and the workplace, making it a key concept for this study (Collins, 2017). Researchers have slightly different ways of identifying patterns and describing the concept of spatial thinking, but they generally agree that it is a set of cognitive skills (reading, creating, interpreting, and explaining visual representations) comprised of concepts of space (distance, orientation, association, and distribution) and reasoning processes to solve problems (Gersmehl & Gersmehl, 2007; see also Golledge et al., 2008; Janelle & Goodchild, 2009, NCR, 2006).

Piaget and Inhelder (1956) first studied spatial thinking to learn how children relate objects to other objects. McGee (1979) was among the first to study spatial thinking in the context of human spatial abilities. Pellegrino et al. (1984) built on McGee's work and identified that spatial thinking has several components – spatial visualization, spatial orientation, and spatial relations. Spatial visualization involves a psychological or mathematical component that relates to the mental manipulation of objects such as rotation or inversion, but it also has geography applications such as Tharp's seafloor cartographic representation (McGee, 1979). Spatial orientation is a geography concept related to map reading or understanding your location on the earth relative to the map (McGee, 1979). Spatial relations pertain to the ability to recognize, associate, and correlate spatial patterns in daily life such as Dr. Snow's famous relational thinking that led him to associate the cholera outbreak in London with the Broadstreet water pump (Gilmatin & Patton 1984; NRC, 2006; Self et al., 1994).

Psychologists are interested in spatial abilities which are natural and different in everyone. Golledge et al., (2008) identified that spatial concepts such as identity, location, and magnitude can be introduced to children. Their research draws from the fields of cognition, neuroscience, and psychology. They make a case for teaching spatial thinking in schools to improve spatial ability. Gersmehl and Gersmehl (2007) claim that spatial thinking is hard-wired in our brains and developed a taxonomy to guide educators on how to include spatial concepts in instruction to increase spatial ability. The concept of continuous development of spatial thinking is supported by Goodchild (2010) who suggested that standards of critical spatial thinking can be taught to students. Goodchild (2006) went so far as to call spatial thinking the fourth R - after reading, writing and arithmetic. Spatial cognition is a framework that is effective for solving spatial problems (Bearman et al., 2016).

Geographers are also interested in spatial cognition. Spatial cognition combines three important concepts in the field of geography – space, reasoning, and representation (Anacta, 2020). Foundational concepts in geography are important in understanding how spatial cognition relates to GIS education. Place location knowledge (PLK) which is the ability to name and locate places on a map is one such foundational concept in geography related to spatial cognition (Torrens, 2001). There is a consensus among geographers that PLK is a key indicator of geographic literacy (Zhu et al., 2015). Wayfinding, or a person's navigational strategy, is a necessary skill (Golledge, 2002). In the process of wayfinding, people make cognitive maps which are mental representations of familiar places or landscapes organized using environmental cognition (Gillespie, 2010).

Bednarz (2019) shares that geography is endowed with three “secret powers” that are based on ways of thinking: spatial thinking, geographic thinking, and geospatial thinking (p. 521). GIS is a discipline that examines spatial concepts and requires geospatial thinking to understand a geospatial phenomenon (Golledge, 2002). A landmark report, *Learning to Think Spatially*, was released by The National Research Council (2006). This report recognized the importance of understanding differences in how people perform spatial tasks. One important outcome of this report is that geospatial thinking was classified as a subset of spatial thinking (Verma, 2014). Verma makes the case that geospatial thinking should be taught as a foundational part of instruction in geospatial education. Geospatial thinking differs from spatial thinking in three ways: geospatial problems are connected to the earth through computer mapping, geospatial problems focus on spatial relations in a geographic context, and geospatial problems include geography concepts (Albert & Golledge, 1999; see also Cutter et al., 2002; Hanson, 2004; Huynh & Sharpe, 2013; Self et al., 1994). Factors such as student and school inequalities, technology access, and data quality can impact students' ability to succeed at geo-enabled tasks requiring geospatial thinking (Kerski, 2003). Maps reflect spatial thinking in the discipline of geography, therefore, the understanding of them represents geospatial thinking by incorporating the how and why of geographical knowledge (Ishikawa, 2013).

Research has shown that self-efficacy is an important concept in considering how students view their abilities to meet the challenges of entering the workplace in the field of GIS (Baker & White, 2003). Generative capability related to self-efficacy refers to the relational measure of a person’s self-confidence in their abilities in any given field (Bandura, 1977). In this study, the broad learning themes emphasized for geospatial education are attitudes, self-efficacy, and performance assessment. Bandura's self-efficacy theory (1977) influenced the research by Baker and White (2003) in which they found that measurement of student attitudes and feelings toward learning geospatial technology could indicate future behavior regarding learning. A national assessment of GIS in US high schools addressed these same themes from the perspective of providing in-service training to help teachers promote self-efficacy among their GIS students (Kerski, 2001). Teaching GIS requires teachers to be facilitators and to let students take the lead, allowing lessons to be open-ended, and welcoming the unknown into the learning environment (Kerski, 2001).

Pulling these theories together in an integrated model, the theory of spatial cognition is effective in explaining different spatial abilities (Hegarty, 2004). Spatial cognition draws from spatial thinking, geospatial thinking, and self-efficacy and forms the spatial perception and spatial positioning that occurs in our everyday life (Sun et al., 2020). This study incorporates spatial cognition as an important framework for geospatial education in preparing students for learning emerging geospatial technologies.

Related Literature

Related literature includes many aspects of geospatial education related to workforce readiness. In the first section, recent spatial cognition research utilizing GIS is reviewed. Spatial cognition is an important framework for how to prepare students to perform the spatial analysis needed when working with emerging geospatial technology in the workforce. The second section will consider the value of geospatial competency models, professional geospatial industry certification, and various geospatial educational models which provide options for student preparation for the GIS workforce. The third section consists of a review of literature on historically significant government milestones in the field of GIS including facilitating understanding the influence of government on geospatial education. Finally, the fifth section includes a review of literature on the emerging drivers and trends of the intelligent web mapping era that offer implications for the future direction of GIS education.

Recent Spatial Cognition Research using GIS

Researchers have found that integration of geospatial technology in the classroom can improve spatial cognition which will improve problem-solving skills - one of the primary skills needed for success in the geospatial workforce (Jadallah et al., 2017; Schlemper, 2018). Spatial cognition includes many processes including the selection of spatial information, processing that information, encoding it, and then storing and extracting it to use for decision making (Sun et al., 2020).

The landmark NRC (2006) report was foundational in inspiring a wealth of early research on spatial cognition following its publication (Gersmehl & Gersmehl, 2007; see also Golledge et al., 2008; Goodchild & Janelle, 2010; Janelle & Goodchild, 2009; Kim & Bednarz, 2013; Lee & Bednarz, 2011). For a better understanding of the impact of spatial cognition in geospatial education, it is important to consider how it evolved in the discipline of geography. Many other disciplines define social and historical characteristics, but geography situates them in a spatial or locational context (Pattison, 1964).

Research indicates that utilizing digital technologies such as GIS in geography curricula is effective as a method to increase spatial cognition and higher-order thinking skills (Collins, 2017; De Miguel Gonzales & De Lararo Torres, 2020). Additionally, research indicates that web mapping is especially beneficial and effective in teaching spatial cognition. For example, web mapping has pedagogical value to demonstrate pattern recognition, visualization, and spatial descriptions for real-world scenarios such as in the case of mapping hurricane intensity, tracking, winds, and storm surge (Perugini & Bodzin, 2020).

Geospatial thinking is a foundational concept to geospatial education; therefore, assessment of geospatial thinking allows educators to measure student understanding of spatial concepts related to the geospatial phenomenon (Golledge, 2002). Researchers are just beginning to evaluate the relationship between spatial thinking and geospatial thinking (Ishikawa, 2013). Very few studies have used maps and the concept of proximity to measure spatial ability and most studies were completed prior to the advent of geo-enabled technologies (Kassahun Waktola & Sishaw Emiru, 2017). More research is needed to explore if spatial cognition is valued by the workforce and how geospatial education can increase geospatial thinking skills through the GIS curriculum.

Preparing Students for Geospatial Workforce

Geospatial technology is a supporting technology in many disciplines with a multitude of applications including environmental, land use, emergency response, military, aerospace, construction, utilities, and mining (Ye & Harding, 2014). Although it is interdisciplinary in nature, GIS is often an independent discipline in academia (Wallentin et al., 2015). Competency modeling is an effective way to identify the core work-oriented tasks for an industry (Dubois, 1993; Dubois & Rothwell, 2000). The method of teaching and measuring the achievement of geospatial competencies is still a matter which lacks consensus in the geospatial community (Jackson, 2020). High technology industries require very specialized skills that are important to the United States economy (ETA, 2003). For this reason, the United States Department of Labor (DOL) published the High-Growth Job Training Initiative (HGJTI) to help meet industry-specific skills required by employers (ETA, Tab 2, 2003). The geospatial industry certainly qualifies as a high-growth industry. Birk (2002) projected the geospatial industry to have an economic impact of $170 billion annually. Birk's prediction has been realized. According to the GeoBuiz Geospatial Industry Outlook and Readiness Index Report (2019), the overall global economic impact of the geospatial industry grew from $1,118.7 billion in 2013 to $2,210.7 billion in 2017. To meet the high-growth rate of the geospatial technology industry, several efforts have been developed to align geospatial technology with the needs of the workforce including competency models, professional industry certification, and geospatial education programs.

Geospatial Competency Models

NASA recognized the enormous market potential of GIS and predicted that a shortage of qualified employees would impact the workforce in the geospatial industry (Gaudet et al., 2003). With a goal of the United States remaining the global leader in the geospatial industry and addressing a lack of qualified candidates for geospatial jobs, NASA funded the Geospatial Workforce Development Center in 1997 at The University of Southern Mississippi (DiBiase et al., 2007; Gaudet et al., 2003). This partnership developed the first Geospatial Technology Competency Model (USM GTCM) which identified the roles, competencies, and outputs of geospatial work. This model identified four categories of competencies – technical, business, analytical, and interpersonal which indicate skills demanded by the geospatial workforce (Annulis, 2004; Gaudet et al., 2003).

The University Consortium for Geographic Information Science (UCGIS) built on the USM GTCM developed by NASA and introduced the first Body of Knowledge (BoK) of Geographic Information Science and Technology (GIS&T) for the United States (DiBiase et al., 2007; Johnson & Sullivan, 2010). The GIS&T BoK covers the concepts, frameworks, and skills needed for geospatial technology and provides support for curricula and educational programs. The GIS&T BoK was published by the Association of American Geographers (AAG) in 2006 and still serves as the model for identifying geospatial knowledge areas. It is updated periodically to meet industry demands (GS&T BoK, 2021). Recent updates of the GS&T BoK included many emerging intelligent web mapping era technologies such as artificial intelligence tools and platforms for GIS, big data visualization, and geo-visualization validating the importance of addressing these trends in geospatial education research.

The National Geospatial Technology Center of Excellence (GeoTech Center) was created in 2008 to develop an up-to-date geospatial technology competency model (GTCM) for the geospatial industry (DiBiase et al., 2010; Johnson & Sullivan, 2010). The US Department of Labor's Employment and Training Administration (DOLETA) provided an update of the earlier High Growth Job Initiative in 2009 which included the definition of six newly recognized geospatial occupations (O'NET, 2010). This update along with the USM GTCM and the GIS&T BoK were influences that led to the development of the DOLETA GTCM which was touted as comprehensive to bring workforce needs into focus (DiBiase et al., 2010; Johnson & Sullivan, 2010).

Higher education's reflection on workforce needs and the development of course offerings teaching innovative geospatial technology could lead to employment opportunities in the geospatial industry (Tsou & Yanow, 2010). The DOLETA GTCM is still generally accepted as a primary reference document and the unifying framework for the geospatial community; however, the rapidly changing landscape of geospatial technology has made it difficult to keep an up-to-date competency model available for the geospatial community (Fagin et al., 2020). Further research is needed to determine if emerging occupations and GIS trends should be considered for future versions of the DOLETA O*NET and GTCM including intelligent web mapping technologies such as programming, enterprise architecture, location-based services, and service-based geospatial solutions in the cloud (Tuscan et al., 2019).

Research by Jackson (2020) has implications for the current study. Jackson's research used a Q methodology approach to examine the perspectives of geospatial professionals concerning the DOLETA GTCM. Stakeholders were asked to sort 62 competencies providing their viewpoint of the relevance of each competency to the geospatial workforce. There are several implications to the current study including Jackson's findings that programming is a valuable geospatial workplace skill and that Q Methodology is an appropriate method to gather stakeholder perceptions of the geospatial workforce.

Profession Industry Certification

There is a gap between the needs of the geospatial workforce and higher education that needs to be addressed by geospatial education (Foote et al., 2012). The geospatial industry is still lacking enough skilled professionals (Davis, 2014). Credentialing GIS practitioners through professional industry certification could address this gap. The Geographic Information Systems Certificate Institute (GISCI) created in 2002 with support from the Urban and Regional Information Systems Association (URISA) became the first organization to implement a GIS certification program (Huxhold & Craig, 2003). This started as a portfolio-based certification but later evolved to be a competency-based exam based on knowledge from the DOLETA GTCM and the GIS&T BoK (Matthews & Wikle, 2019). At least 4 years of work experience and a portfolio is also required to be awarded GISP certification. As of 2019, Matthews and Wikle note that less than 2% of the geospatial workforce had obtained the GISCI certification but 51% of employers agree it is a well-known industry credential. As of January 2019, Li et al. (2020)

reports that there were about 9155 GISP members in the United States. The GeoTech Center began the Geospatial Educator's Certification Program (GeoEdC) with a pilot program in 2020 to provide a certification route for geospatial educators. The goal of this new program is to provide geospatial educators with evidence of GIS competency to teach geospatial courses (GeoTech Center, 2022).

Geospatial Education Models

There are multiple models of geospatial education available such as workshops, short courses, distance education, academic courses, certificate programs, and degree programs. Professional development for educators often occurs in the form of a workshop. Research demonstrates that highly adaptable lessons with resource materials are desirable for both online and face-to-face training (Brysch, 2020). GIS short courses are often offered by software vendors, such as the Learning Plans by ESRI, which offers many online free or paid short courses as well as instructor-led short sessions to provide valuable targeted geospatial skillsets (Bodin, 2018). One new model targeted at meeting the increasing need for technology expertise is the massive open online course (MOOC) (Malhotra et al., 2018; Robinson et al., 2015). According to Robinson et al., (2015) the MOOC model could be beneficial to higher education for addressing emerging technology as it is cost-efficient, scalable, global, and able to address new GIS technologies rapidly. The MOOC concept is well designed for targeted exposure to emerging geospatial technology skills needed for the workforce, but it lacks individualized instruction and effective pedagogy (Malhotra et al., 2018).

Research indicates that early exposure to geospatial concepts increases student spatial and critical thinking skills (Baker & White, 2003; Goodchild, 2006; Kerski, 2003). The Geospatial Semester (GSS) in Virginia is a year-long GIS course for high school students that is supported by James Madison University (JMU) (Kolvoord et al., 2019). The Geospatial Semester is significant to this study in that it provides a pipeline for future GIS courses in higher education. Research shows that students' critical thinking skills on socio-scientific issues are increased with instruction using geospatial technology (Powell, 2020). Research has demonstrated that the Geospatial Semester enhances STEM problem solving and spatial thinking skills (Jant et al., 2019). Bridging the gap between high school and higher education GIS courses by developing cooperative working relationships and alignment of curricular priorities such as the one in the Geospatial Semester between Virginia high schools and JMU can be beneficial to prepare students for the geospatial workforce (AP GIS&T Study Group, 2018).

Institutions of higher education such as community colleges, colleges, and universities are the most prevalent source of geospatial education (Johnson & Sullivan, 2010; Wing & Sessions, 2007). Community colleges offer one of the best opportunities for geospatial education to prepare students for emerging GIS workforce trends. As of 2010, Johnson and Sullivan reported that of the 1,184 community colleges in the nation, over 445 offered GIS instruction in some capacity. As Johnson and Sullivan (2010) point out, one of the strengths of the community college is that it serves a more diverse and unconventional population of students, of which up to three-quarters are working professionals looking to gain skills for employment. With this combined focus of academics (which leads to Associate degrees and certificate programs) and Career and Technical Education (CTE) (which provides mastery of technical GIS competencies), the community college system has the potential for effectively preparing students for the intelligent web mapping trends of the future. Community colleges continue to face several challenges such as program accountability, whether to situate GIS as an academic or vocational program, and a lack of articulation agreements with four-year institutions (Johnson & Sullivan, 2010). Unfortunately, there is a paucity of recent scholarly articles or research on community college GIS programs.

One of the challenges at the higher education level to preparing students for the geospatial workforce is that many colleges and universities still do not offer GIS as a degree program. Many GIS courses are still placed under geography, but there is no consensus among academics or employers about what geography graduates should be prepared to do (Lane & Bourke, 2019). With the expansion of information-based knowledge due to the "internet of things," Lewin and Gregory (2018) warn that curricula and syllabi for courses such as physical geography need to evolve to include geospatial technology including remote sensing, GIS for earth observation, and data acquisition. This is a valid argument as research has proven GIS to be effective in preparing students to acquire geographical knowledge (Healy & Walshe, 2020).

Four-year institutions have a different mission than community colleges and are more likely to consider GIS a science rather than a skill needed for the workplace (Kemp, 2003; Wright et al., 1997). GIS is beginning to be integrated into the curriculum of many disciplines including civil engineering, urban planning, forestry, and architecture. One concern is that when GIS classes are placed in departments other than geography, there is often duplication of effort, and they are placed in the upper 300 or 400 level limiting interdisciplinary exposure (Allen, 2006).

Geospatial trends affecting higher education curriculum are profoundly affecting pedagogy causing geospatial educators to start taking notice of workforce needs (Perez-delHoyo et al., 2020). In STEM education, GIS is becoming known as a transferrable skill that is highly employable (Bearman et al., 2015). While some institutions of higher education attempt to align their curriculum to workforce needs by coordinating with industry partners to conduct a

Developing A Curriculum (DACUM), this is often a very localized effort, not addressing national trends. In Virginia, a collaboration between Virginia Tech and several community colleges created a Virginia DACUM to help higher education meet industry needs (McLeod et al., 2008). Geospatial workforce needs in 2022 are likely different than when this DACUM was completed in 2008. GIS is a dynamic field and geospatial competencies are essentially a shifting target (Foote et al., 2012)

Geospatial Education - Government Influence

To fully understand how higher education can meet the demands of the geospatial workforce, it is necessary to understand that the unfolding of GIS and geospatial education has been a winding path of natural evolution over several decades. The government has influenced geospatial technology on a global, national, and state level. Policies and standards developed by the government on any level have a direct impact on the workforce and on the geospatial education preparation of students for the workforce.

Recent International Influence

Globalism is not only changing the geospatial workforce, but it is also changing the higher education structure and purpose. The Integrated Geospatial Information Framework (UN-IGIF) developed by the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM) was created to support and guide national government GIS needs by addressing global GIS goals and providing collaboration, coordination, and cohesion for geospatial information management (UN-IGIF, 2018). This framework has vast implications for the field of GIS and the global geospatial workforce by promoting geospatial information and facilitating policy formulation, decision-making, and innovation on a global scale.

The United Nations has emerged as the global policy leader in the geospatial field with two significant milestones. The release of the 2030 Agenda for Sustainable Development (UN-ASD) provides a sustainability blueprint for issues such as climate change, disaster mitigation, and urban planning (UN-ASD, 2015). Remote sensing and GIS are important technologies in meeting the UN-ASD goals of sustainable management and environmental conservation (Im, 2020). Sustainability has three pillars – environmental, economic, and social - to explore human-nature interactions and shape future generations (Croog, 2016; Gormally, 2019). Sustainability is an important component of many higher education geospatial curriculums.

The other impactful United Nations global GIS milestone is that the UN-GGIM published the third edition of the "Future Trends in Geospatial Information Management Report: the five to ten-year vision" (UN-GGIM, 2020). This report is the most authoritative and up-to-date reference document available which provides insights into emerging geospatial drivers and trends and reviews the impact and value of geospatial technologies based on the global consensus of GIS experts (UN-GGIM, 2020). The UN-GGIM Future Trends Report notes several issues that rely on geospatial information which have defined our world including climate change, infectious disease, globalization, urbanization, and technology advancements (UN-GGIM, 2020). The purpose of the UN-GGIM Future Trends Report, according to the UN-GGIM, is to support governments in their development of geospatial information management. Despite this global emphasis on geospatial technology from the United Nations, many countries still have not made the connection that GIS implementation is key for their policy development (Scott & Rajabifard, 2017). According to the Countries Geospatial Readiness Index (GeoBuiz, 2019) the United States, United Kingdom, and Germany were noted as the countries that are most geospatially prepared among the 75 countries evaluated.

Addressing this global GIS phenomenon from a geospatial education perspective emphasizes that all 21st-century problems have a spatial component (Kerski, 2020). Geospatial technology and spatial cognition are required to solve 21st-century problems and we must start by teaching spatial thinking in schools (Kerski, 2020; Stoltman et al., 2016). This research will investigate the key global drivers and trends presented in the UN-GGIM Future Trends Report in the context of the gap between emerging GIS technology workforce needs and the preparation of students for the workforce.

Modern Federal Government Influence

Although the federal government has supported mapping and geographic standardization since the 1840s, the 1990s are considered the early stages of the modern age of geographic information systems (Berry, 2013). In the United States, federal geospatial leadership and coordination were solidified with the establishment of the Federal Geographic Data Committee (FGDC) in 1990. The FGDC created the first federal geospatial clearinghouse network initiative to establish government GIS functions, the geospatial data framework, and geospatial standards (FDIC, 1997).

A significant milestone was the Modernization Roadmap for the Geospatial Platform, released in 2009 (Edelson et al., 2013). As a complement to the Roadmap, GeoPlatform was launched in 2011 to provide an integrated collection of federal GIS data and a common map collection that was user-friendly and accessible through a website (Edelson et al., 2013). The GeoPlatform made government GIS data widely accessible for geospatial instruction.

The Geospatial Data Act (GDA) was signed into law in 2018 as part of the FAA Reauthorization Act (Guthrie, 2018). This Act authorizes the FGDC in Code and acknowledges the critical and essential role of geospatial data and technology. The UN-GGIM Future Trends

Report (2020) advocates for national geospatial strategic planning. A new National Spatial Data Infrastructure (NSDI) Strategic Plan was developed by the FGDC to cover the years 2021-2024 (FGDC-NSDI, 2020). This plan included goals that apply to this research as they represent the current United States Geospatial Policy including implementing a national geospatial policy and governance framework, advancing national geospatial data assets and making them accessible, developing open standards-based interoperability to ensure geospatial shared services, and collective governance.

State Government Influence

State governments also recognize the importance of geospatial data and technology. The National States Geographic Information Council (NSGIC) was formed to allow state GIS Managers to coordinate and collaborate on initiatives and policies that serve the best interest of the collective GIS community (Schar, 2021). Although geospatial education is not a primary focus of NSGIC, Virginia has a framework in place to provide coordination between the state government and academia to promote geospatial education.

The Virginia Geographic Information Network (VGIN) (1997) was created in Virginia Code to “foster the creative utilization of geographic information and oversee the development of a catalog of GIS data available in the Commonwealth” (Virginia Code § 2.2-2025). Two of the core functions of VGIN are to create base maps to meet the needs of state GIS stakeholders and to set priorities to meet the needs of stakeholders (state agencies, institutions of higher education, and local governments). This early emphasis on connecting geospatial technology and geospatial education was likely one of the catalysts to the integration of GIS programs in Virginia higher education. The VGIN strategic plan lists facilitating geospatial educational opportunities as initiative 3 under the goal of increasing communication and outreach to the geospatial community (Widner, 2014).

Emerging Divers and Trends in the Geospatial Workforce

Kemp and Goodchild (1991) concluded that the needs of the job market must be considered in the context of the delicate balance between technical skills and academic concepts in geospatial education. This remains true 30 years later and is even more critical with the rapid emergence of global geospatial technology trends. Each of these drivers and trends plays an important role in geospatial education in the emerging intelligent web mapping era workforce, but they do not adequately or completely tell the story of the complexity of real-world trends in the industry. The geospatial education-workforce divide describes the gap between current GIS education programs and the needs of the geospatial workforce to prepare for emerging geospatial drivers and trends. The UN-GGIM Future Trends Report (2020) addresses these emerging drivers and trends.

Driver 1: Technological advancements

Trend 1: Ubiquitous Connectivity. High-speed connectivity, especially 5G mobile communication technology is changing the geospatial industry. In January 2022, 5G services were launched in 46 markets in the US (FAA, 2022). It is the factor that enables many emerging technologies such as artificial intelligence and machine learning which need ultra-high-speed connectivity to perform real-time communications (Pham et al., 2020). While 5G is not yet ubiquitous across the US, it is a driving factor in urban environments where it is available.

In 2009, the federal government provided $7.2 billion in the broadband stimulus which paved the way for 5G implementation (GOA, 2010). However, the surge of employees and students working online from home due to COVID-19 has exposed connectivity issues and broadband infrastructure deficiencies (Franch-Pardo et al., 2020). It revealed that at least 30% of rural, and up to 50%-55% of low-income urban communities in the United States lack adequate broadband access (Settles, 2021). Telehealth is another application in which high-speed connectivity and GIS have played a significant role during the COVID-19 pandemic including the use of artificial intelligence and big data to mitigate the effects of the virus (Pham et al., 2020). This type of life-saving research requires ultra-high-speed connectivity. Not all 5G impacts are positive. Because 5G uses frequencies in the C-band of the radio spectrum, it has caused concerns of hazardous interference of radio altimeters (safety equipment in aircraft). This prompted the FAA to impose restrictions on 5G near airports as they work on ways to integrate 5G and aviation safely (FAA, 2022). The process of moving to 5G technology will take a step forward in 2022 with the decommissioning of the 3G network to free up networks according to the FCC (2021). This may disproportionally impact senior citizens and low-income people who utilize older mobile technology shutting off their ability to make 911 calls and affecting 3G enabled medical devices (Lyons, 2021). Narrowing the digital divide will likely be a concern for Congress and the GIS industry in the next decade.

Trend 2: Cloud Computing and Service-Oriented Architecture. GIS cloud computing involves the storage of spatial data so that it can be accessed remotely to do GIS analysis (VoPham et al., 2018). There are three types of cloud models – GIS public cloud (available to anyone), GIS private cloud (authorized users only), and GIS hybrid cloud (a mix of both public and private). Cloud computing is beneficial to researchers that develop emerging technologies such as environmental epidemiology because researchers can leverage the infrastructure of big data through the cloud making it faster to run analysis on large volumes of data (VoPham et al., 2018).

Linking GIS mapping ability with cloud services is called GIS as a Service (GaaS) (Abdalla and Esmail, 2019). Cloud resources are utilized through the web by three methods according to Leitner (2017) including software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS). GaaS provides the ability to do scalable on-demand geospatial analysis using real-time data (Chelliah & Kumar, 2017, Matney, 2019). GaaS involves big data from big applications. Mapbox collects over 220 million miles of data each day through their geo-enabled web applications including Uber, Snapchat, and Tinder (UN-GGIM, 2020).

Trend 3: Geospatial Internet of Things. The Internet of Things (IoT) has become a popular buzz phrase recently but is often used in a non-spatial context. Geospatial IoT refers to sensors in normal devices such as cell phones or rain gauges and an application or interface (GIS) that connect via wireless communication (the bridge between device and application) (Zhang et al., 2018). This allows for sensor data streaming or real-time data to be consumed, organized, and analyzed in GIS. The definition of real-time GIS is situation-specific. One application may need to update the data source every second such as aircraft monitoring, but another application may update every hour such as weather updates (Harder & Brown, 2017). Real-time refers to data collected on events as they unfold and is not the same as a temporal resolution which is the update interval (Abernathy, 2011).

Trend 4: Digital Twins. Digital twins refer to real-world monitoring using intelligent web mapping era technology to allow for real-time decision-making based on current information using sensors, image capture, and data analysis technology (Shirowzhan et al., 2020). This digital representation of physical assets is different from other three-dimensional (3D) web mapping applications because it uses intelligent web mapping – it is directly linked to data sources through sensors and receives continuous real-time location-based updates in the cloud used to model, simulate and predict in urban environments (Mobisheri et al., 2020). This has been termed the “CloudIoT paradigm” (Botta et al., 2014).

Trend 5: Intelligent Transport Systems and Edge Computing. One area that is has been newsworthy is intelligent transport systems and edge computing. Investment in connected and autonomous vehicles (CAVs) by the automobile industry has led to advanced car sensors with automated navigation to provide location planning, routing, and road attributes (Bagloee et al., 2016). Ensuring safety, interoperability and real-time data updates will be critical for this technology. In the case of CAVs, cloud computing may not be the answer – latency and unpredictable connectivity are cloud computing issues (Barik et al., 2017) that may require CAV navigation and object recognition to happen locally in the vehicle for safety. Edge computing is a shift from centralized cloud computing. The edge means that real-time data is processed and executed on the local device, but artificial intelligence (AI) continues to compute in the cloud at the same time (Barik et al., 2017). Edge computing and the semantic web provide a way for simultaneous creating and collecting spatial data in a format that both the computer and humans can understand. The edge device collects data as it operates, meanwhile the edge gateway pre-processes the data and performs connectivity for data transfer to and from both the devices and the networks (Neil, 2020). The data is primarily stored and processed in the cloud. This interconnection of the real world and information technology has many new innovative applications. Geospatial AI for intelligent mobility even extends to hydrographic underwater surveying which uses autonomous underwater vehicles (AUVs) to capture marine geospatial data (Nippon Foundation & GEBCO, 2021).

Trend 6: Artificial Intelligence/Machine Learning. Automated image analysis and information extraction are two of the most notable and frequent examples of geospatial artificial intelligence (GAI) (UN-GGIM, 2020). Deep learning involves algorithms that enable a machine to organize and learn concepts to complete tasks by training itself (Goodfellow et al., 2016). Deep learning methods have been found to greatly increase the accuracy of automated classification of imagery (Wang et al., 2017; see also Anwer et al., 2018; Huang et al., 2018; Lu et al., 2018; Nogueira et al., 2017). The downside to deep learning when working with image classification is that a large number of samples are needed to improve the generalization ability. The infrastructure is so diverse and complex in urban areas that it can make it hard to differentiate features (Du et al., 2020). Imagery and LiDAR data have been used for many years for the extraction of buildings and urban objects in 2D and 3D at different spatial scales for purposes of urban planning, disaster management, climate studies, and sustainability purposes (Cao, 2020). Fully automated change detection is not yet fully realized; however, Denmark and the United Kingdom have trained models to classify objects in imagery to automatically detect changes in features such as rooftops, solar panels, and buildings with progressing success using big data (UN-GGIM, 2020). The factors driving this technology are cloud computing and sensor technology (both of which are cost-effective) and the availability of an abundance of geospatial data (UN-GGIM, 2020). International standards concerning interoperability between machine learning and other technologies such as GIS are still in development and much collaboration is needed. Also, confidence and trust in the algorithms that determine the accuracy of machine learning are a concern for the geospatial community (Zhang et al., 2020).

Trend 7: Geospatial Visualizations and Immersive 3D environment technology. GIS visualization technology allows for modeling and real-time 3D representations of GIS data (Harder & Brown, 2017). Geospatial technology is a very effective way to provide visualizations used to create a better understanding of data relationships. There are several advantages to 3D web mapping such as the ability to include vertical and volumetric information (Z value), intuitive symbology, bird-eye views, and navigation with the appropriate size and location context (Harder & Brown, 2017). In addition, 3D data showing area, volume, and planar area index are useful for mapping urban environments (Cao, 2020). For example, multi-scale 3D urban information extraction modeling of building information such as building footprints and building height has significant implications for urban planners and can help students understand how cities develop urban design (Huang et al., 2018; Perez-delHoyo et al., 2020).

Two of the most interesting emerging visualization technologies that use GIS data involved the concept of extended reality (ER). Augmented reality (AR) and virtual reality (VR) are immersive technologies that use GIS to merge the real world with virtual computer-generated layers to show proposed structures beside existing ones. Meta, formerly Facebook, is investing heavily in extended reality and rebranded their company to focus on this emerging technology (Meta, 2022). Another potential business use case is the digital twin application of virtual holographic representations of buildings using VR headsets in the Architecture Construction and Engineering (ACE) industry. Research shows that virtual reality has the potential to improve the spatial abilities of students when used in engineering courses (Molina-Carmona et al., 2018).

Driver 2: Rise of new data sources and analytical methods

Trend 1: Big Data and Data Analytics. Data science is a relatively new career path in the geospatial industry that generates valuable insights from big data by using statistics, analytics, computer programming, and algorithms based on location and geography (Provost & Fawcett, 2013). Big data is defined by five V’s – volume, velocity, veracity, variety, and value (Birken, 2019). Wetherholt & Rundquist reported in 2010 that data was being developed faster than it could be leveraged. The volume of data being created now in 2022 is vastly more expansive resulting from new data sources and advanced geospatial analytics that had not been developed ten years ago. There are two types of geospatial data analytics – descriptive and predictive. Data mining is a term that refers to using algorithms to automatically extract useful patterns or knowledge from large data sets for data-driven decision-making (Chen et al., 2015). Visual analytics systems which rely on machine learning computational methods have geospatial applications such as location patterns of purchases in e-commerce, clustering in retail, banking, and telecommunications industries, public needs and service analysis in government, and patient infection and survival analysis in health care (Chang et al., 2020; Chen et al., 2015). Due to the transformative impact of using GIS analysis on big data, it is important to train students in these skills which will be extremely important in the workplace (Perez-delHoyo et al., 2020). Data science is still developing the location and geography components of these disruptive technologies that are impacting the geospatial industry such as machine learning, artificial intelligence, cloud computing sensor networks, and blockchain (Matney, 2019).

Trend 2: Availability of Remote Sensing Data. The remote sensing industry has made significant advancements in data collection methods, sources of data, and sensor systems. High-resolution satellite data is widely available from continuous time series infrared data collected from Landsat 8 every 16 days. This data can be used for many earth observations such as automated land and vegetation monitoring (Im, 2020). Data is also collected from alternative earth observation sources such as small satellites, nanosatellites, CubeSAT, and Synthetic Aperture Radar (inSAR) technology. Aerial imagery has been traditionally captured by manned aircraft. Now unmanned aerial vehicles (UAVs) and High-Altitude Pseudo Satellites (HAPS) provide a more affordable alternative for small-scale imagery data capture which can be combined with automated feature extraction for intelligent mapping applications (UN-GGIM, 2020).

High-quality LiDAR point cloud data is now more available and accessible than ever before with the USGS 3D Elevation program which has a goal of nationwide acquisition of airborne LiDAR in the United States (USGS, 2021). There are several other significant trends in the sources of LiDAR data collection utilized by the geospatial community. Terrain mapping using mobile laser scanners mounted on a vehicle or movable platform is an effective way to collect LiDAR data to create a 3D mapping of urban areas such as tunnels and indoor environments (Gunduz, 2016). Sub-surface mobile lidar mapping of utility and underground transportation systems is another emerging application of this technology (Volchko et al., 2020).

Airborne LiDAR is very expensive, highly regulated, and not flexible due to logistics leading researchers to investigate UAV technology as an alternative for smaller areas of interest (Chung et al., 2019). There is very limited literature available on the potential of UAV technology as a pedagogical tool in educational geospatial-related fieldwork (Cliffe, 2019). UAV technology is an effective lower-cost alternative to LiDAR for several applications important to academic research including forest density and height mapping for small or urban forest stands (McGee et al., 2012; Popescu, Wynne, & Scrivani, 2004; Wallace et al., 2017), environmental research (Manfreda, 2020; Milas et al., 2018), disaster relief mapping (Niethammer et al., 2012), and coastal and wetland applications (Jeziorska 2019; Kalacska et al., 2017). Most of the available research is scientific, not education or pedagogy-related (Cliff, 2019). FAA regulations, privacy concerns, time, cost, and the inability of UAVs to penetrate canopy are still challenges that must be overcome for this technology to be widely adopted for geospatial applications in education (Cliffe, 2019; Klacska et al., 2017).

Trend 3: Ocean and Bathymetry Data. Marine geospatial information is another emerging trend. Less than 20% of the ocean floor is currently mapped which led to the Seabed 2030 project which hopes to create a high-resolution bathymetric (water depth) map of the entire ocean floor by 2030 (Nippon Foundation & GEBCO, 2021). This ambitious project will provide insight into tsunamis, tides, and ocean currents (Nippon Foundation & GEBCO, 2021). The Coastal National Elevation Database (CoNED) Applications Project is utilizing coastal, nearshore, and inland waterway bathymetry as a valuable resource for coastal hazards and sea-level rise research (Danielson et al., 2018).

Trend 4: Linked Data. Geospatially enabled statistics, known as linked data, are beneficial for addressing many social, economic, and environmental issues. Linked data is considered the method that enables data integration (Wiemann & Bernard, 2015). The potential of integrating linked data and spatial data infrastructures (SDIs) could offer solutions to the problems that currently hinder intelligent web mappings such as discovery, access, and use of geospatial data (Wiemann & Bernard, 2015). Semantic and ontology-linked data will be necessary for future autonomous location-based systems to allow for queries that will result in knowledge-on-demand (Wiemann & Bernard, 2015).

Trend 5: Social Media Data. Open social data in cities such as social media data, points of interest, and mobile phone data have made it easier to map patterns associated with social and economic activities in urban areas (Rios & Munoz, 2017; Tu et al., 2017). Social media platforms collect geospatial data through geolocation and GPS tagging. Geolocation is the use of global positioning systems (GPS) or indoor positioning systems (IPS) to determine the current position of a device. Location services can be utilized by any app if the user has given that app geolocation permissions. Although this is a great feature for navigation, it provides a way for tracking the movements and therefore the habits of the device user. One way this is done is through geotagged photos uploaded to social media. Privacy is a concern associated with social media data. Google, Twitter, and Facebook monetize the passively sensed data they collect (Birken, 2019). Our cell phones and social media are collecting passive or ambient geospatial data constantly which can be integrated and merged with other collected data and used to understand patterns that can predict behaviors (Stefanidis et al., 2013).

Trend 6: Crowdsourced Data. Volunteered Geographic Information (VGI) and crowdsourcing are big data intelligent web mapping trends. Crowdsourced data has blurred the concept of what is considered authoritative data and what is non-authoritative. VGI or crowdsourced intelligent web mapping GIS data applications such as OpenStreetMap rely on users to use, update, and evaluate content in real-time (Birken, 2019). This is a departure from traditional desktop GIS which requires production processes and does not allow for real-time updates. Open-source software and GaaS have helped GIS to evolve from a theoretical into an applied design discipline that has great potential in higher education (Perez-delHoyo., 2020).

Driver 3: Evolution of User Requirements

Trend 1: Digital Natives. Digital natives (millennials, Generation Z, and Generation Alpha) who were born or grew up during the age of digital technology have different expectations of user experience. They expect geospatial technology to be mobile, frictionless, and convenient and they value personalization, the ability to interact with data, digital networking, and recognition (likes) (UN-GGIM, 2020). Partly due to this user requirement, digital mapping is now available to almost everyone who has access to the internet. Field data collection has been revolutionized through the use of GIS applications such as Collector or Survey123 on mobile devices. Intelligent web mapping technology through mobile devices has not only drastically increased the volume and type of data that consumers can access but also their demands on the ease of use for this data.

Trend 2: Open Data and Exclusion. Open data is free and available for anyone to use who has access to the internet. Open data is generally provided by authoritative government sources but is now increasingly also provided by collaborative sharing on portals and services, and vendor websites such as ESRI's Living Atlas or ArcGIS online. Open data comes with direct costs including data collection, preparing the data, data sharing and publishing, maintaining and updating datasets, protecting the data, privacy, and confidentiality, and staff resources (Johnson et al., 2017). There are also indirect costs of open data that are not straightforward or immediately evident. The challenges of failing to meet the anticipated benefits of open data are considered indirect costs.

The digital divide is considered an indirect cost leaving jurisdictions with limited accessibility through digital inequalities in a state of data poverty (Warf, 2018). The prevalence of web mapping has raised questions of shifting power relations and a discussion of the social and political construction of geospatial technology around the topics of inclusion, exclusion, and knowledge claims (Elwood, 2009). Globally the digital divide can be observed along economically developed and underdeveloped countries. It can also be observed in gender accessibility of the internet with women representing two-thirds of those internationally who do not have internet access (Joiner et al., 2015). In the United States, it is often an urban/rural inequality with a lack of internet coverage in rural areas (Warf, 2018). Although it does not address the digital divide issue of internet coverage, public participation GIS (PPGIS) has brought about a transformation from exclusive government curated spatial data to a model where grassroots organizations and citizens have more access to data and also the ability to create data (Elwood, 2010).

Geospatial technology holds promise in addressing social priorities as a means of bridging the digital divide. Open data also has the potential to increase citizen empowerment, support marginalized groups, reduce social-economic disparities, and investigate population migration (UN-GGIM, 2020). Unfortunately, research indicates that open data does not always translate into citizen participation or citizen engagement, transparency, or accountability which are often stated goals of government open data programs (Johnson et al., 2017).

Trend 3: Demand for real-time information provision. Mission ready means that geospatial data is ready for analysis without much effort from the user and has linked identifiers for effective use and interoperability with other data being used. Authoritative data sources such as those from government sources that are open and available to download by anyone are typically considered mission-ready. User expectations for the applications of this data are increasingly focused on how GIS can solve societal issues.

Emergency management needs mission-ready data with real-time information provision. FEMA, NOAA, and the EPA have increasingly adopted geospatial-based operation models that monitor weather, air quality, water quality, pollution, floods, earthquakes, and fires (Ray et al., 2017). Public safety examples of the geospatial IoT that are connected through intelligent web mapping include practical transportation applications such as real-time tracking of police officers, snowplows, busses, or trash trucks in cities as well as real-time traffic flows, road conditions, and accidents (Harder & Brown, 2017). Visualization skills are useful to represent emergency response situations such as storm surge and wind velocity (Perugini & Bodzin, 2020).

Presenting the data in visualizations supports decision-making and enhances the impact of the data.

Geospatial technology has a critical role in developing a sustainable future. The 2030 Agenda for Sustainable Development from the United Nations (UN-ASD, 2015) addresses how GIS can support climate change initiatives through near real-time information provision. Some of the geospatial user requirements for climate change and sustainability include environmental concerns, economics, natural resources, resource security, biodiversity loss, deforestation, pollution, and water stress according to the United Nations (UN-ASD, 2015). For example, GIS can study the performance characteristics of two classes of vegetation models: undercurrent and altered climates (Rizzo, 1998). Additionally, the geospatial IoT has applications for climate studies using sensors to track wind speed and direction using intelligent web mapping in urban environments (Huang et al., 2018).

Another significant requirement for real-time information provision is the role of geospatial technology in renewable energy. Solar, wind, biomass, hydropower, and geothermal are examples of renewable energy sources that can be analyzed with geospatial technology. Intelligent web mapping is used when studying urban energy trends by real-time data collection of building temperature data, surface thermal conditions, and building solar radiation levels (Yang et al., 2017; Yu et al., 2016).

Trend 4: Emphasis on Urban Environment/Smart City Solutions. The term smart city has evolved due to urbanization occurring in major cities around the world (Shirowzhan et al., 2020). Cities monitor wastewater and utilities such as water, electricity, and other public services (UN-GGIM, 2020). Urban planning has redefined the expectations of users to include a seamless experience between outdoor and indoor mapping. Smart cities require high-quality geospatial data to manage assets such as building automation systems (BAS) for offices and data centers often referred to as smart buildings (Neil, 2020). Authoritative data is also needed to create native urban 3D models such as Google Street View (Nebiker et al., 2015). Smart cities are not just interested in mapping their land use, they also maintain real-time sensor networks for temperature, pollution, and moisture that allow for data-driven decision making (Harder & Brown, 2017). Cities utilize radio-frequency identification (RFID) on connectors to acquire real-time data and integrate it with GIS (Harder & Brown, 2017). The GIS output for this real-time data is often a real-time operations dashboard allowing visualization of the status of data.

Driver 4: Industry structural shift

Trend 1: Open Geospatial Science and collaboration. Open geospatial science involves sharing resources among the geospatial community such as publications to share research, evidence-based reproducible workflows, innovative collaborations, best practices, and lessons learned shared at conferences and user group meetings. This involves making open data free and accessible through online data portals or application user interface (API) which allows for data download. The Open Geospatial Consortium (OGC) is promoting the use of open geospatial data and the development of standards for open data (Bakillah & Liang, 2016; Mobasheri et al., 2020). Ease of use is an important consideration for more effective data use. Open-source geospatial software is gaining traction because it is free, accessible and the source code can be modified.

Trend 2: Private Sector Growth/Influence. The number of private and non-government sector companies in the geospatial industry has grown substantially with a particular focus on the urban environment. Cross-sector collaborations, the growth of the web and mobile mapping, and public participation in GIS are all contributing factors in the shift from government agency silos to the rise of the private sector geospatial industry (UN-GGIM, 2020). The World Geospatial Industry Council (WGIC) (2021) was formed to facilitate knowledge transfer and represent the business interests of the global geospatial industry. There is also a shift from physical to digital platform business models led by Amazon, Apple, and Microsoft which has blurred the lines between producers and consumers (UN-GGIM, 2020). For example, Uber does not own any vehicles but is the largest transportation company in the world. Uber combines intelligent web mapping technologies (geospatial location data, geospatial analytics, cloud computing, visualization, and route networks) to provide data-driven solutions (Green, 2020). Many of these technologies were considered disruptive but are now common and accepted. Other intelligent web mapping era technologies that are currently emerging now such as artificial intelligence and machine learning are anticipated to grow as a result of private sector investment and will likely become commonplace in the next decade (Bughin et al, 2017).

Trend 3: Talent and Consumer Shift. Many students are being exposed to geospatial data earlier than ever before through the digital technology of gaming and smartphones (Mani et al., 2016). This validates early geospatial experts and researchers who advocated for teaching geospatial concepts in elementary (Goodchild, 2006), middle (Baker & White, 2003), and high schools (Kerski, 2003). Virginia is ahead of the curve on creating a geospatial pipeline with the high school Geospatial Semester (Kolvoord et al., 2019). Advocacy for geospatial education is important for the digital native students of today who are already fluent with using location-based services such as PokemonGo, SnapMap, and Uber on their smartphones (Kamel Boulos et al., 2017).

Changes are needed in geospatial education to meet the accelerating rate of new skills needed in the geospatial industry. This could involve not only changes to the higher education curriculum but also reskilling and upskilling of existing employees in the geospatial workforce (UN-GGIM, 2020). Digital transformation will increase demand for skilled employees in the areas of data science and analytics, computer science, and data visualization in the geospatial workforce in the next five years (UN-GGIM, 2020). Conversely, many of the repetitive geospatial jobs such as data collection, production processes, and basic data interpretation will become automated, lessening the need for people to do those jobs (UN-GGIM, 2020).

The need for the geospatial community to collaborate on diverse teams and meet challenges is evident in the teams that are working together to integrate artificial intelligence and statistics with real-time location data (Bughin et al, 2017). Sector skill approaches to geospatial industry competencies are a way to design a curriculum for professional development or training that aligns with the skills required by the geospatial workforce and bridges the skills gap. The EO4GEO is one example of a sector skills approach involving 13 European Union countries. This effort bridges the skills gap by providing geospatial training for emerging workforce needs in the sector of earth observation/space and geographic information (EO4GEO, 2021).

Trend 4: Enabling Diversity. The geospatial industry has traditionally faced an underrepresentation of women and diversity in the workforce (Reid, 2019). However, in recent years, the geospatial workforce has become more diverse in age, gender, race, and cultural background (UN-GGIM, 2020). There are 106 Historically Black Colleges and Universities (HBCUs) in the United States, most of which do not have GIS programs, but do emphasize Science, Technology, Engineering and Math (STEM) education disciplines which have applications in many emerging geospatial technologies (Malhotra et al., 2018). Interdisciplinary integration of GIS in higher education, especially HBCUs, can build diversity of thought and background in the field. To enable diverse professionals to adapt to the emerging needs of the geospatial industry, mentorship programs and professional networks are beneficial to encourage communities of common interest.

Driver 5: Legislative environment

Trend 1: Digital ethics, cybersecurity, and privacy. The UN-GGIM Future Trends Report (2020) is based on an international perspective and addresses the value of national geospatial strategies. In the United States, President Trump signed the Geospatial Data Act (GDA) into law to solidify the essential role of geospatial data and GIS technology by creating a National Spatial Data Infrastructure (NSDI) Strategic Plan to cover the years 2021-2024 (FGDC, 2020). This plan sets national geospatial policy and provides provisions for collective governance, interoperability, data quality metrics, and data accessibility. This is important as the volume of new data leads to questions on data ownership and who should be allowed to benefit from the value of the data created. Digital rights management issues include not only ownership but also licensing, pricing, and open data harmonization. The responsibility of geospatial data use has brought up the question of ethics, privacy, and cybersecurity (Scull et al., 2015).

One topic that is not commonly addressed in geospatial education is the ethical use of geographic data (Scull et al., 2015). Typically, in academia, the privacy of sensitive geospatial data is handled by aggregation (averaging across larger spatial units), perturbation or differential privacy (noise is added randomly to the data), or anonymization (disclosive attribute information is replaced by generic data) (Birkin, 2019). The increase in web mapping on location-enabled mobile devices and social media can lead to socio-spatial vulnerabilities not only in academia but in society (Elwood & Leszczynski, 2011). To address these concerns, national and international government initiatives are beginning to address the ethics and responsibilities associated with geospatial applications.

Trend 2: Pace of Digital and Technology Change. Many of the emerging intelligent geospatial technologies are being developed along with other technologies. Data interoperability between GIS and other industries is challenging as the formats may not be compatible (Bakillah & Liang, 2016). Standards are needed to enable effective collaboration so that stakeholders can share data, collaborate, and implement systems together (Bakillah & Liang, 2016). There is much work to be done in developing standards. It would be prudent to be proactive rather than reactive in developing standards for emerging geospatial technologies, but that is rarely the case.

Trend 3: Pressure on Government Institutions. Protection of GIS data is not provided in national standards, nor has it been constructively legislated which leaves the potential for abuses. Geospatial technology has outpaced the legislative process on these crucial concerns (Wetherholt & Rundquist, 2010). Government agencies are experiencing rapid change in the way they respond to geospatial demands. The government is currently the provider of authoritative data, but that role will increasingly require more accountability, collaboration, integration, and flexibility to remain relevant. The UN-GGIM Future Trends Report (2020) highlights the shift in government from spatial data infrastructure to a spatial knowledge infrastructure that develops not just geospatial data but also geospatial capacity including data networks, geospatial policy, analytics, and expertise. The UN-IGIF (2018) has emphasized that all governments must address governance and policy issues.

Summary

Derived from the contributions of literature in the field of geographic information systems and geospatial education, this review explored the body of existing research on how geospatial education is meeting the emerging needs of the geospatial workforce during the intelligent web mapping era. An overview of research gaps was identified to address the changes needed in the geospatial education curriculum. As Rickles and Ellul (2017) point out, because of the rapidly changing nature of GIS, it is difficult for educators to keep up to date with emerging trends and to include cutting-edge GIS in their curriculum. Therefore, reviewing gaps in the current geospatial education curriculum according to literature is beneficial to identify how the curriculum should be updated to meet current trends.

The overall strengths of the body of literature are in the areas of the historical foundation of geospatial education. There are many research studies and literature reviews that include a review of significant research in the early phases of GIS and the benefits of GIS to develop spatial cognition. Multiple research studies address the historical foundation of geospatial education and demonstrate support for the need for geospatial education. Another strength is that the literature provides in-depth reviews of existing competency models, the influence on curriculum, and the impact on the geospatial workforce is reviewed in the literature.

The primary weakness of existing literature is a paucity of research on the developments in the GIS workforce in recent years and how the curriculum should be changed to meet emerging geospatial technology demands. There are only two research studies that address the intelligent web mapping era trends concerning the geospatial workforce. There are no studies that research this topic with geospatial education. Additionally, there are no studies that use the most authoritative and most recent source of information on emerging geospatial workforce trends – the United Nations Future Trends Report (2020) – as a primary literature source. These significant gaps in research offer implications for the future direction of GIS education. The next steps for research are to investigate specific trends identified as research gaps in the literature to examine how these trends can be integrated into the higher education curriculum. Exploring stakeholder perception can provide insight into the problem that the geospatial curriculum has not been updated to reflect the skills needed to meet the emerging intelligent web mapping era trends of the geospatial workforce. Additional qualitative research in the form of an exploratory collective case study was conducted to discover how geospatial technology education can meet emerging geospatial workforce needs in the Commonwealth of Virginia.

CHAPTER THREE: METHODS

Overview

The research for this exploratory collective case study sought to examine the perceptions of geospatial stakeholders in the Commonwealth of Virginia concerning the readiness of students to meet the emerging workforce needs of the geospatial industry in the intelligent web mapping era. The design model for the study, research questions, as well as information about the study setting, participants, procedures are covered in this chapter. Next, the setting, participants, procedures, and techniques for the data collection and data analysis process are discussed. Data collection techniques included individual interviews, Q methodology, and document review. This study protected the confidentiality of the setting and the participants. This chapter concludes with the background of the researcher, a discussion of trustworthiness and ethical considerations, and a summary of the chapter.

Research Design

Qualitative case study as a research design is used across many disciplines. In education, a general approach to qualitative research is recommended according to Merriam (2014). Rebolj (2013) shares that case studies have several defining characteristics such as the identification of real-life cases. Also, they are bounded and able to be described in parameters. The case study approach allows for the investigation of the GIS education phenomenon in-depth in a real-life context (Yin, 2018). It also allows for the perceptions of participants which weave an intricate fabric on the topic (Creswell, 2018).

This study was structured as a qualitative study with a multiple case study research design. Collective case studies “understand a specific issue, problem, or concern” and use multiple case studies to highlight the issue (Creswell, 2018, p. 98). The collective case study approach used was exploratory in that it investigated the perceptions of geospatial stakeholders within the context of preparing a geospatial curriculum to meet the needs of the geospatial industry related to emerging geospatial drivers and trends. The exploratory collective case study was conducted with four cases. This design defined each case as a group of stakeholders (academia, state government, local government, and industry). This study examined the phenomenon of geospatial education of students in higher education in the Commonwealth of Virginia. The phenomenon was examined from the perspective of geospatial stakeholders in Virginia. The Commonwealth of Virginia provided the real-life context for the study. Data was collected from individual interviews and Q methodology. Documents from multiple sources were also investigated as a source of data for the study.

This study was situated, interpretive, and naturalistic in approach, which is the basis of qualitative research (Flick, 2019). It used multiple methods and reasoning to make sense of participants' perceptions in the context of the geospatial education preparation of students for employment in the geospatial workforce. A qualitative approach was the appropriate type of research for this study because the researcher sought to understand a difficult problem and collaborated directly with participants concerning the context of how geospatial education is related to preparation for geospatial employment. The case study approach provided an in-depth understanding of the phenomenon within the real-life context of the setting of geospatial employment. The phenomenon for this study is geospatial education and how well it is preparing students for the geospatial workforce. Other approaches to research could work for this study. A quantitative survey would reveal what should be included but not the "why" or the "how" based on participant perception. Therefore, a case study approach was selected to allow the researcher to collect and analyze multiple perspectives from interviews, Q methodology, and documents.

Research Questions

The following questions guided this exploratory collective case study that examined Virginia geospatial employers' perceptions regarding the geospatial workforce and how geospatial education can prepare students for geospatial careers.

RQ: How do educators, state government mangers, local government managers, and industry stakeholders perceive the emerging geospatial drivers and trends that are impacting the geospatial workplace?

SQ1: How do geospatial stakeholders describe emerging technological advancements in the geospatial workforce?

SQ2: How do geospatial stakeholders perceive the rise of new data sources and analytical methods in the geospatial workforce?

SQ3: How do geospatial stakeholders describe the evolution of user requirements?

SQ4: How does the industry structural shift in the geospatial workforce impact geospatial stakeholders?

SRQ5: How do geospatial stakeholders characterize the geospatial legislation environment?

Setting

The Commonwealth of Virginia was the geographic location for this study. In this state, the Virginia Geographic Information Network (VGIN) sets policy for geospatial best practices and procedures for state and local government and higher education. In addition, planning district commissions (PDC) are established which lead collaborative GIS efforts for each region. These PDC Regions loosely form GIS User Groups which meet quarterly and provide technical guidance and professional development for GIS professionals in that region. Geospatial stakeholders in these regions from academia, local government GIS offices, and GIS businesses attend these meetings. State agencies also hold similar quarterly State GIS User Group meetings for state GIS stakeholders. Additionally, the Virginia Association for Mapping and Land Information Systems (VAMLIS) is the professional industry organization for GIS professionals in Virginia, providing networking and a myriad of diverse GIS professional development sessions at the annual conference.

The Commonwealth of Virginia was chosen because of the strong collaborative environment in which GIS managers meet with GIS educators in the Regional GIS User Group meetings. This provides a more likely environment for collaborative progress and responsiveness to employers' needs in the education of GIS students in Virginia colleges and universities. The VGIN Strategic Plan (2009) has listed the following strategic goal for GIS education in Virginia (Widner, 2014):

> VGIN 2010-2015 Strategic Initiative 3: Facilitate geospatial educational opportunities Outcomes: Provide a gateway to information related to GIS education in the Commonwealth; Specialized training opportunities for VGIN customers that focus on specific areas of the geospatial industry.

The Commonwealth of Virginia also has a robust GIS education program on the K-12 education level. The Geospatial Semester, founded at James Madison University, has provided geospatial education in Virginia High Schools across the state to more than 5000 students in the past 15 years (Kolvoord, 2020). The educational pipeline approach has proved successful and makes Virginia a unique setting to analyze the quality of geospatial education regarding the workforce as it is firmly established on both the high school and university levels.

Participants

Since the study examined geospatial stakeholders' perceptions of emerging geospatial trends to prepare students for the geospatial workforce, all participants met the criteria of being currently employed in a full-time GIS leadership role such as manager, supervisor, lead, or professor for at least one year. The sampling procedure of criterion sampling was utilized. Criterion sampling is purposeful according to Creswell (2013). Participants were invited to participate by email and then selected for the sample by the researcher based on responses to a prequalification survey (Appendix C) and were included in one of four cases. The cases were defined as geospatial higher education, state government GIS, local government GIS, and the geospatial industry. The sample size was twelve interviewees that were chosen from a sample pool of over 100 geospatial stakeholders in the 21 planning district commissions in Virginia. The VGIN statewide GIS contact database which is available on the VGIN website was used to obtain the list of potential participants and their contact information. The sampling criteria defined that each participant must be employed in a leadership role in a geospatial role and must have been employed in that capacity for at least one year. Ideally, these stakeholders also participate in Regional GIS User Groups but that was not required.

A total of 41 participants (including all interview participants) were also chosen from the same sample group for the Q methodology. This sample size was appropriate because Creswell (2013) shares that for multiple case studies, it is preferable to select "unusual cases" and "describe multiple perspectives" (p. 158). Brown (2008) explains that Q-technology was explicitly designed to discover and analyze similarities and differences in individual subjective viewpoints by combining aspects of both qualitative and quantitative research. Brown explains that a small sample size of below 50 participants is appropriate because Q methodology is exploratory and interpretation-intensive. McKeown and Thomas (2013) believed that 30-50 participants were the appropriate range and that the participants should have a defined viewpoint that is substantial to the research topic.

The demographic sample was diverse in age, gender, employer, and geography. The VGIN GIS contact database only contained a small number of people with an ethnicity other than white which limited the diversity of race available for this study. Two women of color (one of Asian descent and one of Middle Eastern descent) are represented in this study. Stakeholders were selected for each of the cases from a wide range of perspectives. See Table 3.1 for an overview of diverse employers represented in each case and Figure 3.2 for a map of the participants by Virginia Planning District Commission Region to represent the diversity of geography.

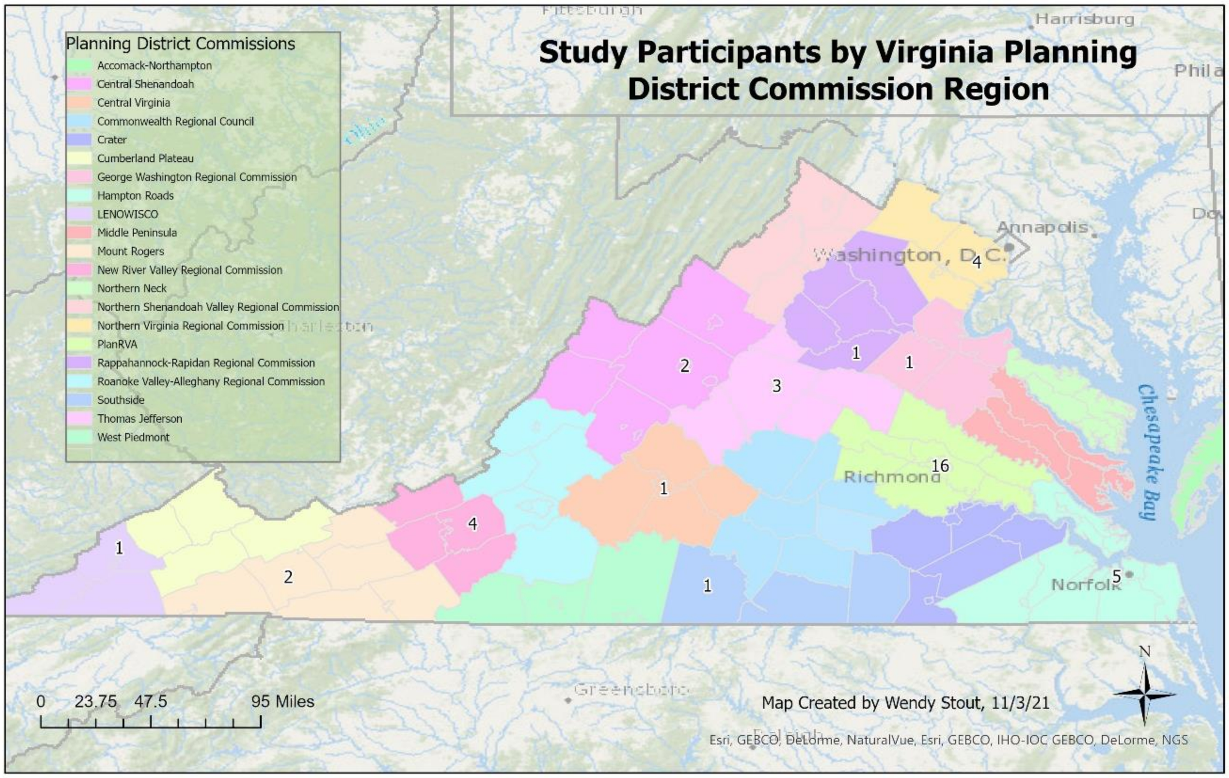
Table 3.1

Stakeholder Employer Overview

Academia	**Industry**	**State Government**	**Local Government**
College of William & Mary James Madison University Mary Washington University Old Dominion University Radford University University of Richmond University of Virginia Virginia Commonwealth University Virginia Tech	AECOMM Clearion ESRI Dewberry Fugro GeoDecisions King-Moore Outdoor Access RES Timmons	VA Dept. of Conservation and Recreation VA Economic Development Partnership VA Dept. of Emergency Mgmt. VA Energy VA Dept. of Environmental Quality VA Dept. of Forestry VA Dept. of Health VA Dept. of Transportation VA Dept. of Wildlife Resources VA Outdoors Foundation	Fairfax County Goochland County Halifax County James City County Norfolk Orange County Rockingham County Smyth County Virginia Beach Wise County

Figure 3.1

Study Participants by Virginia Planning District Commission Region



Procedures

Following Liberty University's Institutional Review Board (IRB) approval (Appendix A), a pilot study was conducted that included vetting of the questions with two individuals who met the study criteria. This pilot study gave the researcher direction on research design and planned interview questions. According to Yin (2009), pilot studies allow researchers to improve interview skills and learn more about the phenomenon researched. The pilot allowed for the test participants to not only answer the interview questions but also provide feedback on their perspective of any needed changes. The pilot was conducted by the Zoom web conferencing platform. It provided an opportunity for note-taking and to gain insight into the dynamics of participants sharing ideas.

After the pilot study, the researcher selected the other participants for the study using a purposeful criterion sampling approach (Creswell, 2013). Selected participants must be employed in a leadership role in a geospatial position and must have been employed in that capacity for at least one year to participate. A recruitment email was sent to potential participants to share the information about the study and request information to verify if they met the criteria to participate in the study (See Appendix B). The email addresses of the participants are public and were obtained online from the VGIN contact database found on the VGIN website. Participants were selected from regions across the state and different types of employers including local and state government, academia, and the geospatial industry. Only educators from four-year higher education institutions were selected to avoid the potential of researcher bias as I am currently a community college GIS educator. Participants completed a survey to determine eligibility (Appendix C). Participants were notified in writing of their selection by sending them an email. All participants agreed to an informed consent (Appendix D) form before any data was collected. See for participant consent/assent form.

The study utilized three methods of data collection. The first method was twelve individual interviews. The researcher took detailed notes during the interviews. The interviews were also recorded using Zoom Recording on the laptop computer. The interviews were transcribed using the automated Zoom transcription feature and then verbatim by the researcher. The transcriptions were then provided to participants to verify by member checking (Creswell, 2013). This method ensured that participant perceptions were accurate.

The second method utilized was Q methodology. Forty-one participants (including all interview participants) were selected using the same selection criteria used for interviews from the VGIN database. Participants were sent a link in an email to complete the Q-sort. Data was collected via the Q methodology website (qmethodsoftware.com) (Q Methodology, 2021). The Q methodology data has been digitally preserved and is password protected.

The third method was document analysis. Analysis of documents provided additional information about the phenomenon in combination with the other methods of data collection. GIS course offerings and GIS programs from Virginia public universities were collected. Analysis of online documents from the DOLETA website including the GTCM and the O*NET were analyzed (O*NET, 2022; GTCM, 2022)

The comparison of the data collected from interviews, Q methodology, and documentation provided insight into geospatial stakeholders' perceptions of how to prepare students to enter the geospatial workforce. Interview data were analyzed using pattern matching, cross-case synthesis, and participant and expert review (Yin, 2018). The Q methodology was analyzed using Pearson Correlation Matrix and factor analysis. The researcher used analytic memo writing to analyze and reflect on the documentation data that was collected. Saldana (2013) recommends these approaches to identify patterns, themes, or categories in the data.

The Researcher's Role

As a qualitative researcher, I serve as a human instrument (Lincoln & Guba, 1985). As a human instrument, I need to bracket my "prejudgments, biases, and preconceived ideas" (Moustakas, 1994, p.85). This was especially important as I have served in the capacity of both a geospatial educator and geospatial employer in the manager role in the past.

My previous positions have given me a unique perspective as both an educator and a GIS professional. My previous work as Director of Spatial Analysis and Geography Professor at the University of Richmond as well as my role as Geospatial Adjunct at the College of William and

Mary has provided me with both GIS teaching experience and opportunities to collaborate with university geospatial educators across the Commonwealth of Virginia. I am currently employed at two Virginia Community Colleges as an Adjunct GIS Professor and full-time as an Instructional Technologist. In my role for NASA Virginia Space Grant Consortium, I was a team member on a grant that sought to form GIS programs at 23 community colleges in the Commonwealth of Virginia and developed the Virginia DACUM. This exposure to the process of geospatial education program development was community college-specific; therefore, because of my current and former association with the Virginia Community College System, this study did not include community college educators to eliminate potential researcher bias toward this type of higher education. I served as a GIS Specialist for FEMA during Hurricane Katrina and several other disasters. I often find that I also have a personal bias to see geospatial trends in the context of emergency management.

My previous employment as Geospatial Program Manager of the Commonwealth of Virginia places me in a unique position to understand the needs of geospatial employers in Virginia. In this role, I was the primary liaison between VGIN and local and state government GIS managers as well as GIS educators. I worked with each of the planning district commissions to assist with organizing the Regional GIS User Group meetings. I was the peer-appointed leader of the State Agency GIS User Group. I also worked closely with state legislators and other geospatial leaders on the VGIN Board who set geospatial policy for the Commonwealth of Virginia. In this role, I was in a position of authority and developed professional relationships with geospatial managers and supervisors in all regions of the state. Because of these past professional relationships, I believe that potential participants were more willing to be open to participating in the study and more comfortable in responding to interview questions.

These former positions provide me with first-hand experience in geospatial education and GIS expertise. I also hold GISP (Certified GIS Professional) industry certification. However, I do not possess expert knowledge on the emerging geospatial workforce trends of the intelligent web mapping era or expertise on how geospatial education can address these trends which was the focus of this study. My biases based on my previous experiences as a geospatial professional in state and federal government and as a geospatial educator needed to be bracketed. I also needed to be careful to listen intently to my participants' perceptions about the phenomenon (Creswell, 2013).

I am not currently in a role of authority over geospatial employers or educators in the state. I do not have any direct work relationship with any participants currently. I have worked closely with many of the participants in the past on projects and in a professional capacity directly related to my previous roles which are no longer applicable. My current experience as a geospatial educator is with the community college system. This study evaluated perceptions of geospatial employers on the preparedness of students from higher education institutions (excluding community colleges) to enter the geospatial workforce.

Data Collection

Rigorous and meticulous data collection is a hallmark of good qualitative research. Yin (2009) advises that multiple sources of data should be collected as evidence for case studies. For this study, individual interviews were collected first, then Q methodology was conducted, and finally, documentation was analyzed with the other two data sources. Documentation included GIS course offerings from Virginia colleges and universities and GTCM and O*NET documents from the DOLETA website. This sequence was chosen because interviews were the primary data source. The Q methodology was used to either confirm or provide contrary data to what was collected in the interviews as well as provide additional information from geospatial leaders. As Yin (2009) recommends, I used the documentation to confirm and supplement the previously collected data. A primary component of my case study was triangulation. Yin (2018) discusses that data triangulation is an effective way to improve the accuracy of data evidence by collecting and comparing multiple sources of data. Yin (2018) advises the use of multiple sources of data as evidence for case studies to support construct validity.

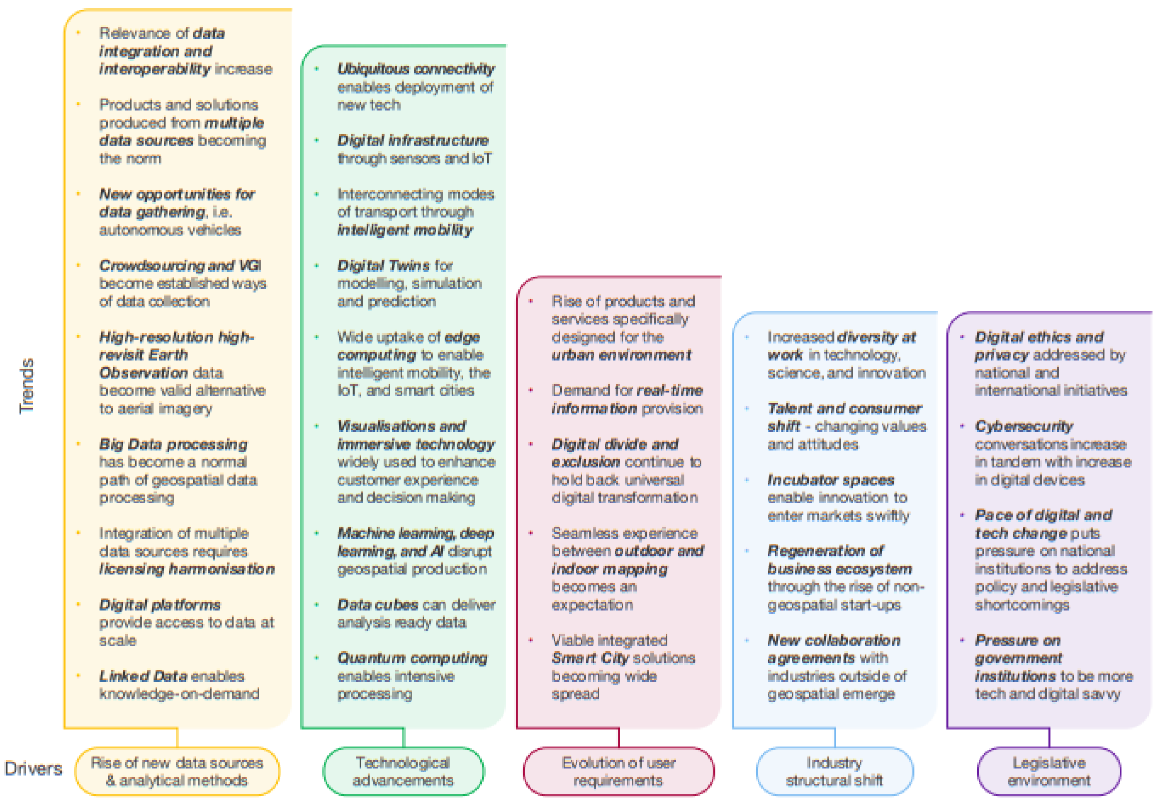
Interviews

The interviews with participants utilized standardized open-ended questions with twelve participants. This data collection strategy is appropriate for qualitative research according to Brinkmann and Kvale (2015) in that it attempts to understand the lived experience of participants. Interviews are appropriate for case studies and can help the interviewer to build "an in-depth picture of the case" (Creswell, 2013, p. 162). Each interview was conducted by the Zoom web conferencing platform online and lasted for approximately one hour. Interviews were recorded using the Zoom recording application. Research questions were addressed by the interviews. In literature, DiBiase (2007) emphasizes bridging the classroom-to-employment gap in geospatial education. These gaps were addressed by the research questions. The interviews were transcribed verbatim. Experts reviewed the interview questions before IBR approval. The experts were Liberty faculty who hold Doctor of Education degrees. This provided validity and allowed me to make recommended revisions.

Research gaps revealed the need for more information on addressing how the geospatial curriculum can be updated to reflect the skills needed to meet the emerging trends of the geospatial workforce. Research identified significant gaps between workforce needs and the current GIS curriculum. Several of these emerging GIS trends mentioned as gaps by previous researchers include 3-D modeling, real-time analysis, web GIS, mobile applications, big data, open data, cloud data, application development and programming, UAVs, remote sensing, and crowdsourcing (Câmara et al., 2009; Goodchild, 2010; Wallentin et al., 2015). The interview questions reflect the drivers and trends (Figure 3.2) listed in the United Nations Future Trends Report (UN-GGIM, 2020).

Figure 3.2

Geospatial Drivers and Trends (United Nations Future Trends Report, 2020, p. 16)



Interview questions one and two are standard open-ended knowledge questions (Patton, 2015), and were designed to provide participant experience with the phenomenon. These questions establish the participant's experience and background with geospatial education and are non-threatening and establish rapport with the researcher. Creswell (2013) shares that interview protocol can help participants to be open to talk and should be bounded at the beginning and end of the interview. I followed this procedure with my interview questions. Baker et al. (2012) shares that geospatial education is needed to address the needs of the workforce. Therefore, it is important to ask questions that help participants to reflect on their own geospatial education experiences and collaborative workforce efforts relating to geospatial education. Questions one and two were designed for this purpose.

1. Please introduce yourself to me as if for the first time.
2. Describe how you entered the GIS profession including any geospatial education/training/coursework that you have completed?

The following interview questions were designed to gather additional information for research and address both the central research question and the sub-questions to gain additional information about stakeholder perceptions. These questions which put the participant in the role of expert also provided insight into the current practices of geospatial employers and the reality of their experiences (Patton, 2015). As Wallentin et al., (2015) noted in their study, stakeholders can have diverging opinions on geospatial workforce needs. Expert interviews can be helpful to understand the geospatial job market. Further, interviews provide an understanding of how ready universities are to prepare students to meet the needs of geospatial employment based on perceptions of employers of the drivers and trends of the geospatial workforce. Tuscan et al., (2019) recognized that emerging GIS trends need to be addressed in future versions of the Geospatial Technology Competency Model. To address emerging trends in geospatial education, it is important to identify which trends are important to stakeholders in the Commonwealth of Virginia. Understanding geospatial leaders' perceptions can help institutions of higher learning be better prepared and more informed on how to prepare students to meet the needs of geospatial employers.

Questions 3-8 address both the central research question and sub-question 1 on the perception of geospatial stakeholders on the emerging geospatial technological trends under driver 1 (technological advances). Sub-question one provides an opportunity for stakeholders to provide their perception of the core technological advancements that should be included in the Advanced GIS curriculum to prepare students for success in the geospatial workplace. Edelson et al. (2013) notes that the *Road Map for 21st Century Geography Education Project* recognized gaps in the learning progression of geographic practices. Advanced GIS curriculum must address progressions of understanding related to emerging technology.

3. In what ways has geospatial technology evolved since you first entered the GIS field?
4. How have emerging geospatial technologies changed the way your organization functions?
5. Describe how your organization is creating or utilizing real-time data or sensor data?
6. How is your organization utilizing 3D, web mapping, and visualization of data?
7. In what ways does your organization use cloud computing and GIS as a Service?
8. What are the most important current emerging geospatial technological trends that should be addressed in geospatial education?

Questions 9-12 address both the central research question and sub-question 2 on the perception of geospatial stakeholders on the emerging geospatial trends under driver 2 (rise of new data sources and analytical methods). Questions regarding this driver provide insight into the perceptions of employers on advanced data sources and uses and how they can be utilized in geospatial education.

9. What sources of data does your organization utilize or create?

10. How has your organization used remote sensing data such as Orthoimagery, LiDAR, and UAV?
11. What data integration, data interoperability, and data shareability challenges has your organization experienced?
12. Please provide any examples of how your organization has engaged with Crowdsourcing or Volunteered Geographic Information.

Questions 13-17 address the central research question and sub-research question 3 on the perception of geospatial stakeholders on the emerging geospatial trends under driver 3 (evolution of user requirements). GIS impacts in fields such as emergency management, climate change, and renewable energy have led to opportunities in the geospatial workforce for learning new skills. Training to prepare geospatial educators to teach real-world project-based learning is needed to prepare students for the geospatial workforce (Howarth & Sinton, 2011; see also Demirci, Karaburun & Unlu, 2013; Lane & Bourke, 2019).

13. Describe the competencies (tasks) that should be taught in all introductory geospatial education curricula to prepare them for the workforce?
14. If you could personally receive professional development with no time or cost constraints, what GIS-related training topics (competencies) would you choose?
15. Why would you choose those particular topics (competencies)?
16. What GIS-related professional development topics (competencies) would you choose as the training priority for your staff or potential employees to prepare them to meet geospatial trends that may impact your organization?
17. Reflecting on your experience as a geospatial stakeholder, what advice would you give to geospatial educators as they develop their Advanced GIS curriculum?

Questions 18-21 address the central research question and sub-research question 4 on the perception of geospatial stakeholders on the emerging geospatial trends under driver 4 (industry structural shift). These questions address meeting the changing needs of the geospatial industry and how geospatial educators can prepare students for the geospatial workforce. These questions reflect on what the geospatial industry can do to prepare students for geospatial employment. Geospatial education has been documented by many studies that have researched the effectiveness of geospatial education pedagogy concerning geospatial workforce competencies in higher education (DiBiase et al., 2006; see also Prager & Plewe, 2009; Van Orshoven, 2009; Ahlqvist, 2011).

18. Describe the impact of open geospatial science including open data and open GIS software.
19. How can your organization collaborate with higher education to prepare students to succeed in your sector?
20. How can higher education develop partnerships that will be meaningful to preparing students for the geospatial workforce?
21. How do you expect the geospatial workforce to change or develop over the next several years?

Questions 22-24 address the central research question and sub-research question 5 on the perception of geospatial stakeholders on the emerging geospatial trends under driver 5 (legislative environment) and how it impacts the geospatial workforce. The UN-GGIM Future Trends Report (2020) noted that there is a lack of legislation addressing many of the issues that surround emerging geospatial technology.

22. What topics would be most important to the geospatial industry for legislation to address?

23. What type of standards are important to your organization?
24. How can geospatial ethics be taught in geospatial education?

Question 25 is a one-shot question (Patton, 2015) that will allow the participant to provide insights based on his or her personal experiences.

25. We've covered a lot of ground in our conversation, and I so appreciate the time you've given to this. One final question… What else do you think would be important for me to know about how geospatial education can meet the needs of the geospatial workforce?

Q Methodology

Q Methodology was used to supplement and validate the data collected by the primary data collection method of interviews. Q methodology is a research method developed by William Stephenson as an alternative approach to factor analysis based on the concept of subjectivity related to how people attribute meaning to their world including their perceptions (McKeown & Thomas, 2013). Q methodology is considered neither qualitative nor quantitative – it is generally considered a mixed method of data collection with attributes of both. Since this research is following a qualitative method of design, Q methodology will be used to provide additional detail about the perspectives of GIS stakeholders in Virginia. The strength of this data collection method is that it reveals viewpoints of participants to be "understood holistically and to a high level of qualitative detail" (Watts & Stenner, 2012, p. 2). Yin (2018) validates the use of quantitative and mixed-method data collection as part of an embedded case study evidence. Yin advises that supporting data collection methods should be considered as "only one component" over the overall data analysis (Yin, 2018, p.120-121). In this case study, Q methodology is appropriate as a supporting data collection method that either confirmed or provided contrary data to the data collected from the interviews. Stone and Turale (2015) note the goal of Q methodology as studying thoughts, opinions, perceptions, beliefs, and attitudes which is appropriate for this study:

> Q methodology allows us to identify, understand, and categorize individual perceptions and opinions, and then cluster groups of these categorizations. This research approach also emphasizes the qualitative how and why people think the way they do, but not how many people think a certain way. (p.183)

Q methodology studies describe a population of viewpoints and correlate people across a sample of ranked statements as opposed to R methodology which studies a population of people and correlates traits across a sample of persons (Durning, 1999; Van Exel & de Graaf, 2005).

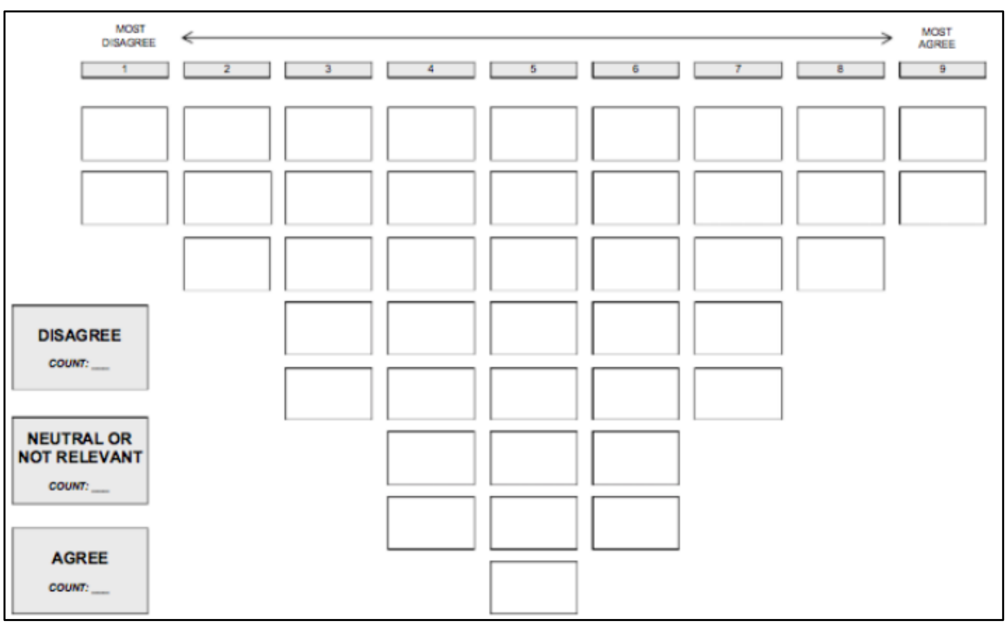
Participants for this study received an email with a link to access the Q-sort and the protocol (See Appendix E). They agreed to participate in the study and completed a pre-qualification survey to confirm their eligibility. The Q methodology is completed in five steps (Cuppen et al., 2016). It begins with selecting the concourse. The concourse can be considered a comprehensive group of statements about a particular topic of research interest. The concourse encompasses all views about the subject according to Wright (2013). This research used the drivers and trends listed in the United Nations Future Trends Report (UN-GGIM, 2020) and scholarly research to develop a concourse for the Q-study.

The second step was to develop the Q-sample from the concourse. Van Exel and de Graf (2005) advised that the Q-sample should consist of between 40-50 statements. The Q-sample for this study is the 45 statements on which the participants provided their perceptions (Appendix E). The Q-sample was reviewed by a domain expert for validity. The researcher selected the study participants in the third step. They were chosen using the same criteria used to select the interview participants. A total of 41 GIS stakeholders in Virginia in their leadership roles for at least a year were included as participants. The data collected was the sorting of the statements and qualitative input from the participants in the form of open-ended questions (Appendix F).

Q methodology data collection is done online through the Q methodology website (qmethodsoftware.com). Directions were included to guide participants in completing the Q methodology and an instructional video was provided. For the fourth step, participants were given the 45 individual statements (Q-sample) and asked to pre-sort them into three categories not relevant, neutral, and relevant. Participants were then asked to rank the statements according to their viewpoints by placing the statements into a pyramid which allowed only one ranking of most relevant (+5) and one ranking of least relevant (-5) (Figure 3.3). After completing the Q-sort, participants were asked to complete open-ended questions to describe the reasoning for how and why they chose the ordering on their pyramid as well as questions about demographics, their perceptions of geospatial education, and the geospatial workforce trends. The fifth and final step of analysis and interpretation will be discussed later in this chapter.

Figure 3.3

Sample Score Pyramid for Q-Sorting (Van Exel & de Graaf, 2005)



This method of data collection has been used successfully for GIS data collection previously to determine participant perception on the DOLETA GTCM (Jackson, 2020). The outcome of the qualitative and quantitative analysis of the Q methodology will add to the Jackson (2020) research by identifying potential future competencies based on participant perception of important emerging geospatial trends. The Q Methodology used in this study addresses the central research question and all sub-research questions.

Document Analysis

This study included an examination of site documents from the Commonwealth of Virginia and DOLETA GTCM and O*NET documents. Documentation examination of GIS course offerings from Virginia colleges and universities was completed by reviewing online course catalogs and course offerings. GIS course offerings and programs from Virginia colleges and universities reveal insight into geospatial education in Virginia. Data from the DOLETA was reviewed including the GTCM and O*NET careers. Yin (2009) shares that case studies benefit from documents in the data collection process and that “documents play an explicit role” in case studies (p. 103). For this study, documents serve as an important guide to provide insight into the perceptions of geospatial educators on the preparedness of students to enter the geospatial workforce. The researcher notes that these documents were created for purposes other than this research and may or may not apply to this study. Review of geospatial course offerings and programs and DOLETA documents serve to answer both the central research question and sub-research questions revealing possible gaps between industry requirements and current geospatial higher education courses.

Data Analysis

This collective case study involved multiple forms of data collection to achieve triangulation. Creswell (2013) shares that triangulation increases credibility. The researcher analyzed each set of data and synthesized the findings across all three of the sets of data that were collected. This study included data collection in the form of interviews, Q methodology, and document analysis. Saldana (2013) shares that data analysis starts when data collection begins and recommends qualitative researchers use coding for data analysis.

For this study, data analysis began by making a detailed description of the cases and the setting in addition to organizing data files. Bracketing was used as a tool to organize the data. Pattern matching was an appropriate strategy to identify literal or theoretical replication in this study (Yin, 2018). Cross-case synthesis using a case-based approach was applied appropriately to this multiple case study because it analyzed “within-case patterns across the cases” (Yin, 2018, p. 196). Saldana (2013) recommends that the researcher read through the transcriptions carefully by paragraph, highlight, underline, make notes, and pre-code the data. The researcher followed this model by using a multiple-column template to group and organize the data systematically into categories (Saldana, 2013). The codes that have similar attributes formed the categories. Analytic memoing helped organize the data and identify recurring themes (Creswell, 2013). Creswell also shares that category aggregation will facilitate the development of themes from the categories. The written narrative description of the case and its context was developed from the themes. Direct interpretation and developing naturalistic generalizations of lessons learned were also part of the data analysis (Creswell, 2013).

Q methodology data was analyzed using two methods – a correlation matrix which summarizes views of participants, and factor extraction which seeks patterns of opinion

(Steelman & Maguire, 1999). Participants completed a Q-sort activity by sorting their views on the Q-sample statements on a preference pyramid. A correlation matrix was created which reveals the relationships between variables found during the sort of the Q-sample and identifies the shared views of participants (van Exel & De Graaf, 2005). Q-sorts near +1.00 reveal similar beliefs, while Q-sorts near -1.00 reveal no similar beliefs, and 0.00 values reveal no association between beliefs (Watts & Stenner, 2005). The researcher analyzed how participant viewpoints are similar or different by conducting a factor analysis (Simons, 2013). Factor analysis identifies patterns in the data by finding participants who ranked statements similarly (Shemmings, 2006; Zabala & Pascual, 2016). The Q-sorts can be analyzed to rank statement totals, normalized scores for factors, descending array of differences for factors, statement factor scores, factor characteristics, standard error of differences, a correlation between factor Z-scores, distinguishing statements, and consensus statements. These analysis tools were used to compare the Q-sort with the data from the interviews.

Additionally, Yin (2018) recommends participant and expert review. For this study, participants reviewed the transcripts of interviews to ensure accuracy and provide the researcher with any needed changes. Additionally, an expert from Liberty University reviewed the data and analysis to offer feedback and suggestions for improvement. Creswell (2018) shares that this analysis strategy is effective to establish trustworthiness, credibility, dependability, confirmability, and transferability (Creswell, 2018).

Trustworthiness

Creswell (2013) shares that trustworthiness is demonstrated by addressing credibility, dependability, transferability, and confirmability. He refers to this process as validation and views this as a “distinct strength” of qualitative research (p. 250). The reason this is such a strength according to Creswell is that the researcher invests significant time with the participants and as a result weaves a thick, rich tapestry of description.

Credibility

Credibility is utilized to demonstrate the accuracy or internal validity of the data that will be collected (Creswell, 2013). As recommended by Yin (2009), triangulation which is achieved by "multiple sources of evidence" (p. 114) was used in this study to increase credibility by providing three sources of data collection – interviews, Q methodology, and documentation. Additionally, an expert review was utilized to increase trustworthiness. Liberty University faculty with the Doctor of Education degree reviewed my interview questions and Q methodology and provided feedback on my data collection and data interpretation plan.

Dependability and Confirmability

Member checking was included to increase the dependability and confirmability of the data. Transcriptions of participants' interviews were provided to participants to review to ensure the accuracy of the data collected (Lincoln & Guba, 1985). Direct quotes were used to document the thoughts of the participants and increase the confirmability and authenticity of the data (Creswell, 2013). Confirmability was used to establish the value of the data according to Creswell. Also, a pilot study was conducted. The researcher conducted a pilot interview with two geospatial stakeholders to ensure questions were effective and would produce information relevant to the phenomenon being studied (Yin, 2009).

Transferability

Transferability is an aspect of qualitative research that Creswell (2013) states will allow readers to be able to decide if information can be transferred to other contexts. Creswell shares that "thick description" (p. 256) is needed to ensure findings are transferable from researcher and participants. This study developed naturalistic generalizations that Creswell (2013) shares will allow people to glean from the case and apply to “another similar context” (p. 206). The external validity of the study in qualitative research is also addressed by developing a good quality description in the case study using Yin’s (2018) characteristics of an “exemplary case study” (p. 201-206). The description portion of the case study should be significant, complete, consider alternate perspectives, and composed in an engaging manner (Yin, 2018).

Ethical Considerations

Ethical considerations were an important part of this study. Institutional Review Board (IRB) approval was sought before any data collection. Confidentiality was also addressed. Participants in both the interviews and the Q methodology were provided pseudonyms for the protection of their identity. Participants agreed on the set location for interviews which occurred on the virtual Zoom web conferencing platform. They signed an informed consent form and were told that participation in the study was voluntary and they could withdraw at any time. Two participants were determined to not be qualified based on the pre-qualification survey. No participants deemed qualified due to the prequalification survey withdrew from the interview. For data that was collected on participants, password protection is used for electronic data storage. The researcher is the only person to know the password. Data will be stored in a locked cabinet in the researcher’s home for three years based on records retention recommendations and will be destroyed at the end of the records retention timeframe.

Summary

This exploratory collective case study sought to discover how geospatial technology education can meet emerging geospatial workforce needs in the Commonwealth of Virginia. A case study was appropriate for this study because it investigates the phenomenon in-depth in a real-life context (Yin, 2009). This study utilized data collection methods of interview, Q methodology, and documentation. Data analysis was conducted utilizing the Saldana (2013) approach of coding data into categories and themes. Multiple sources of evidence were compared by using triangulation and additional measures such as pattern matching, cross-case synthesis, correlation matrix, factor analysis, and participant and expert review to establish trustworthiness credibility, dependability, confirmability, and transferability. The IRB approval process and participant confidentiality addressed the ethical considerations of this study.

CHAPTER FOUR: FINDINGS

Overview

The purpose of this exploratory collective case study is to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia. This chapter reviews the analysis of the data collected from individual interviews with geospatial stakeholders, Q-methodology, and documentation and shares the findings from the study. Each case consisted of three stakeholders from GIS sectors in the Commonwealth of Virginia. The cases reflect the sectors of academia, local government, state government, and industry. The cases were reviewed as individual cases based on their specific sector and then cross analyzed for pattern and theme identification. The chapter begins with descriptions of the characteristics of the interview and Q Methodology participants. Next, the themes and patterns generated from the data obtained through individual interviews, Q Methodology, and documentation are shared. Outlier data and findings are shared followed by research question responses. A summary of the findings closes the chapter.

Participants

This collective case study utilized the online Zoom meeting platform. Twelve individual GIS stakeholder interviews were conducted across four case studies. These included three GIS representatives from Virginia colleges and universities, three GIS managers from Virginia state government, three Virginia GIS local government stakeholders, and three Virginia GIS industry managers. All of the stakeholders were deemed qualified by the pre-qualification survey. All of the stakeholders who were interviewed also participated in the Q-methodology. An additional 7-8 participants were selected to do the Q methodology in each case study for a total of 10 Q Methodology stakeholders for the state government, local government, and industry case studies and 11 stakeholders for the academia case study. These 41 study participants capture a wide range of perspectives.

Of the 41 total participants, 28 were male and 13 were female. All participants had 10+ years of GIS work experience. The average number of years of GIS experience was 20.79 years. Participants held a variety of work roles as seen in Table 4.1.

Table 4.1

Stakeholder Primary Work Task Overview

Work Role	Number	Percentage
GIS Program Management	10	24%
Geospatial Education	8	19.5%
Positioning and Data Acquisition	2	5%
Analysis and Modeling	8	19.5%
Software and Application Development	7	17%
Other	6	15%

The Geographic Information Systems Professional (GISP) certification is held by 14 participants. Additionally, 12 participants hold other related industry certifications including ASPRS Remote Sensing Certification, Project Management Professional (PMP) Certification, GIS Specialist for Fire (GISS), ESRI Desktop Certification, ESRI ArcPro Certification, ESRI GeoData Certification, Professional Geologist Certification, Remote Airman Certification, American Institute of Certified Planners (AICP), and Certified Database Administrator. Most participants do not hold degrees in the field of GIS (see Table 4.2) but most do hold either a Bachelor's degree or a Master's degree (see Table 4.3).

Table 4-2

Stakeholder GIS/Remote Sensing Specific Education Overview

Education Level	Number	Percentage
Degree in GIS/Remote Sensing	9	22%
Certificate in GIS/Remote Sensing	9	22%
No Degree or Certificate in GIS Remote Sensing	23	56%

Table 4-3

Stakeholder Education Level Overview

Education Level	Number	Percentage
Some College	1	2%
Bachelor’s Degree	15	37%
Master’s Degree	18	44%
Doctorate Degree	7	17%

GIS user group meetings are popular with stakeholders in Virginia with 95% of study participants attending these meetings. VAMLIS membership is slightly less popular with 63% of study participants joining the professional organization. Most of the participants are hiring managers (90%) for their employer and 60% supervise employees. All except two participants are actively involved in GIS policy discussions at their organization.

Demographic information provides an overview of the participants for the study which is beneficial for analyzing similarities and differences within each case and across cases. The participants who completed the in-depth interviews are described in the results section to provide a portrait of each individual. Participants in both the interviews and the Q methodology were provided pseudonyms to protect their identity.

Results

This qualitative collective case study includes the results from data collected using individual interviews, Q methodology, and document review. Theme development was the first step of data analysis. Next connections to the research questions are explained based on responses by the participants. Throughout this section, direct quotes from participants are included to provide authentic first-hand stakeholder perceptions. Screenwriter Robert McKee (2003), writes that “Stories are how we remember; we tend to forget lists and bullet points” (p. 51). This results section will begin with the compelling stories of twelve Virginia GIS stakeholders.

Individual Interview Results

Data collection began with individual interviews with 12 Virginia GIS stakeholders. The interview questions were centered around the drivers and trends in the UN-GGIM Future Trends Report (2020) to determine stakeholder perceptions. The interviews were conducted over the Zoom web conferencing platform and were video recorded, transcribed, organized, and then analyzed. Member checking was performed on the transcripts which were reviewed by the interview participants for accuracy and completeness of their statements (Creswell & Poth, 2018). Pattern analysis and cross-case synthesis were used to compare the cases as recommended by Yin (2009).

Academia Case Study

Job. Job is a Senior GIS architect for a large public university in Southwest Virginia. He shared that he sees his job as lowering barriers to the use of GIS technology so that academic experts and administrative professionals can do their functions more efficiently. He has 15 years of GIS experience. He is mostly self-taught in GIS having essentially created his position as a graduate student by identifying a need and offering a solution. Over the years other departments have seen the value of GIS services and his role has expanded exponentially. What started as server-side Enterprise GIS now includes cloud computing, software as a service, infrastructure as a service, advanced application development for specialized functions, and systems integration work. Job calls this truly transformative.

Job is on the cutting edge of geospatial intelligent mapping trends. He has been involved in implementing real-time comprehensive campus headcounts which integrate wireless controllers to determine the number of devices connected to every access point on campus in five-minute intervals. He explained that the data is de-identified and aggregated to provide a

JSON feed of building-level timestamped data. Job then can use Geo Event server to create a feature service in an intelligent web map that can be used in a dashboard to show a near real-time streaming view of campus headcount data. This is useful to emergency management, campus police, housekeeping, and even the dining hall. He shared that his next big project is to work with campus electric services to pull in utility telemetry using the same basic principles as the headcount to provide the volume of chilled water and electric consumption using automated sensors and the Internet of Things. He will then aggregate other temporal data to show patterns. Job is also involved in using 3D visualization for campus mapping with stacked floor views by loading data from CAD to GIS. Job noted that there are many 3D applications not only for built environments but also for the natural environment. He explained how the campus is using remote sensing with high-resolution RGB imagery, UAVs, LiDAR, and Landsat data for analysis in forestry, geography, plant pathology, and agronomy. Job has also been involved in community broadband and bike surveys which utilized crowdsourced data and field data collection using Survey 123 and Arc Collector.

With all of this heavy emphasis on emerging GIS trends, it is surprising that Job felt that the basics of spatial thinking were the most important skill to be taught in higher education GIS programs. He said the basics were profoundly important including understanding how to solve spatial problems. Job believes students should have a good balance between fundamental theoretical grounding and exposure to technology trends. Through his many collaborative interdisciplinary interactions, Job has developed the rare ability to see the high-level big picture view of how GIS fits into typical roles in organizations. To accommodate these roles, he recommends pathway specialization for higher education GIS programs. He offers three areas of focus– spatial analysis, programming, and Enterprise GIS.

According to Job, the spatial analysis specialization would prepare students to be GIS Analysts and would provide training in GIS fundamentals and software skills. The programming specialization would provide the GIS fundamentals but would also offer computer science knowledge, data structures, and algorithms, familiarity with databases, software engineering, and GIS-specific programming courses such as Python. Job envisions this as a possible double major scenario. The third specialization is Enterprise GIS which requires GIS fundamentals and systems architecture, design, engineering, implementation, and integration skills. Job relates that cloud computing, SaaS, systems integration, system design, implementation, and planning are also important to this specialization which he views as an interdisciplinary degree with Information Systems. He believes that these three specializations will prepare students to meet the emerging geospatial workforce skills of the intelligent web mapping era.

Matthias. According to Matthias “My gateway drug to GIS was really landscape change.” A remote sensing class in 1996 eventually led to a Master’s degree in Environmental Studies and a career focused on how green infrastructure impacts blue infrastructure which he explains is more simply described as how landscape affects aquatic communities. Matthias is an Assistant Professor of GIS for a large public university in Central Virginia. He has been in his current role for 24 years. He holds ASPRS industry certification. He is active in the Virginia geospatial community and participates in user group meetings and VAMLIS. In addition to his role in academia, Matthias also works for the Army Corps of Engineers.

With over twenty years of higher education GIS/remote sensing teaching experience, it is not surprising that Matthias has some strong feelings about what GIS students should be taught. He emphasized critical thinking and specifically spatial thinking skills as foundational and of critical importance. He advocated for GIS education to prepare a “well-rounded student” by giving students exposure to many aspects of the technology. He recommended an octopus approach. He shared that this could be accomplished by two methods. The first is by having a central focus or question such as environmental applications and studying it from multiple perspectives. For example, each class meeting could focus on a different sector such as health, forestry, biology, ecology, or habitat. This gives students “a deeper learning on the subject matter.” The second method is the T approach which exposes students to as many horizontal skills as possible but then the student would specialize in one vertical skill of particular interest. He claims this makes the student more marketable for the geospatial workforce.

Mathias felt strongly that ESRI ArcPro was the software that should be taught to students. He said, “if ArcMap is even on the computer, you’re doing an incredible disservice to the student.” His reasoning for this is that educators should stay up to date with current trends. Some of the trends that Matthias recognizes as important in the intelligent web mapping era are the Internet of Things, mobile mapping on cell phones using collector and Survey 123, UAVs, real-time data using sensors, 3D visualizations, programming (Python), and artificial intelligence/deep learning. He shares that AI technology has been around in the Bioinformatics and pharmaceuticals field for many years and that this technology is utilized heavily in his current academic research. Matthias is a leader in the geospatial industry using AI/deep learning to do fish counts in Virginia bodies of water.

Matthias expects GIS to become more interdisciplinary with it either required for or interwoven in many degree programs. He expects GIS to increase in value particularly in the field of sustainability. He values teaching standards and ethics as part of education. He also values authoritative open data and points out that educators only have students for a limited number of hours and that time shouldn’t be spent cleaning data. He thinks that GIS students should also know how to network, create infographics and presentations, and learn how to "tell a compelling story" with GIS. He recommends incorporating current events in the classroom whenever possible to show the geospatial connection in the real world. Matthias says that projects should "mimic real life." Along with that same philosophy, he advocates internships and sees them as a good way for students to get their start in the geospatial industry.

Elijah. Elijah is one of the founding fathers of GIS with 50 years of GIS experience. He holds a doctorate and is currently a GIS Associate Professor for a public university in Northern Virginia. To talk with Elijah, he is unassuming and humble but there is a tremendous depth of knowledge and experience that spills out with a little prodding. GIS algorithms using computer punch cards in Fortran and focusing on Location-Allocation problems. His first position was as a methodologist at Statistics Canada where he was responsible for developing GIS strategies to disseminate census data. He was a member of the team that developed and published the first digital mortality Atlas of Canada. A first for that time as all the work was competed using the then new Arc/Info system. That system required a special climate-controlled room to hold the computer and consoles, two of which were capable of displaying in color - a big deal in 1982! He then took a position with Environment Canada working for the Canadian Land Management System (CLDS). The CLDS was housed and operated the first operational government GIS in the world and was developed to capture, manage, update, and analyze environmental data for Canada. There he met Roger Tomlinson, an instrumental developer of the CLDS GIS which led him to be recognized as the "Father of GIS" . The CLDS GIS a was a raster-based system. Elijah's first role was to develop a utility that could translate the system to a vector-based GIS. Once completed, he was asked research a topic that was beginning to attract attention - climate change. His efforts resulted in the creation of Canada's first climate change map that presented a potential scenario of shifts in ecosystems because of climate warming.

Elijah completed his Ph.D. research in climate change using GIS and has continued this research throughout his career. This work is primarily raster-based. He has owned his own company and worked as a consultant before joining academia. These impressive career-spanning credentials are unmatched by most GIS professionals, making his viewpoint one of both historical and contemporary significance.

Elijah advises educators to focus on the fundamentals such as spatial thinking. He states "I think once a student understands the fundamentals of GIS, how GIS actually works, you could segue your way into the analytical aspects with a much better understanding of the possibilities." He further explains that not having this fundamental grasp, will hamper their ability to grow in the field. Certificates, while beneficial as a start point, at best provides basic entry level GIS skills. A GIS program has the time and available courses to provide both the foundation skills and expertise in spatial analysis as applied to a range of problems, not only in Geography but Environmental Science, History, Economics, Health and most other disciplines. Elijah explains that combining GIS with data science\data analytics is where GIS is headed and any university GIS program that can incorporate elements of these disciplines into a GIS program will provide their students with sought after skills that will make employment almost automatic. He argues that this type of program would attract very bright students that would not normally pursue the discipline if a certificate was the termination point.

Another type of program that Elijah believes would be very successful is one that focuses on the needs of communities like counties and cities emphasizing how GIS can support emergency management, urban development and planning, and smart cities. Focusing on this area also provides more opportunities for internships. This is a growing segment of the GIS market will provide more job opportunities and opportunities for community engagement. The importance of internships cannot be over-stated. There is clear anecdotal evidence that internships lead to jobs. He advocates for the integration of GIS and intelligent web mapping in other disciplines such as historic preservation, biology, and business to prepare students for an increasingly GIS-based workforce. Elijah tells a humorous but tragic parable of the integration of GIS in the Business School that did not happen because the College of Arts and Sciences and the College of Business could not agree on which one would pay for the adjunct to teach the class. He estimates that the GIS program at his university would be up to 30% larger if they had built the business component into it.

Industry Case Study

Simon. Simon believes that the utility of geospatial data will "explode as it drives transport and mobility solutions through interconnected solutions." Simon is a GIS Product Manager for an international company that has active contracts in Virginia. He started in precision agriculture working for a startup before landing in his current role. He has 24 years of experience in the GIS industry, a Bachelor's Degree in Geographic Information Systems, and industry certification as an ASPRS Certified Photogrammetrist and as a Project Management Professional.

Simon shares that GIS changes rapidly and that his role in the industry relies heavily on emerging geospatial trends. His role focuses on the trends of 3D visualization and modeling, automated intelligence, big data predictive analytics, interactive virtual worlds, and digital twins of the built environment. His employer is in the business of data acquisition including imagery and LiDAR data using advanced sensors and creating ancillary products using automated intelligence/machine learning that has applications in many different sectors including emergency management and energy markets. Simon's employer even collects transportation data with mounted sensors to capture data on rail and roads. He shares that the industry is moving toward business models that include shared ownership of data where it is collected once for a specific purpose, but then the company can sell it multiple times for many purposes. Simon explains that imagery and LiDAR formats have been standardized but Oblique imagery format is not yet standardized. The reason for this is that patents slow the process down until the patent runs out.

Simon advises educators to consider data science including how to automate and extract information from data. He explains that analytical skills are important for GIS employees in addition to thinking critically, problem-solving, communication, sales skills, project management, and general information technology skills. Simon shares that the cloud has revolutionized IT in recent years, reducing the IT staff in his office from 15 to 1 person. He shared that "employees must also be able to convince senior management to take chances on innovation, write compelling and convincing business cases, detail risks and rewards, and do SWAT analysis so you can work on and obtain funding for the cool trending technologies of tomorrow." He believes that all GIS education programs should include basic programming skills and basic Python scripting. He predicts that over the next five years there will be a merging of remote sensing and the gaming industry through visualization. In Simon's experience, collaborative grants are the best way for universities to engage with industry through application development research.

Joseph. Joseph holds a Bachelor's degree in Geography and frames his viewpoint through the lens of a geographer and through his current role as a GIS Senior Project Manager for an international company that has active contracts in Virginia. When asked what should be taught in all geospatial education he responded that “there’s some people I know, actually disagree with me on this, but I think generally geography - cultural and human geography is closely tied to GIS.” Joseph, who holds a GISP, has 14 years of GIS experience including a short stint as a local government GIS manager. His current employer is primarily focused on data acquisition, data cataloging, and quality review of geospatial remote sensing data including imagery, bathymetry, and LiDAR. They engage with federal agencies such as FEMA and USGS using many of the emerging geospatial trends.

Joseph related that FEMA is using crowdsourcing for damage assessments using Twitter and other social media platforms. They are also using machine learning to track the dispersion of people away from an event by looking at the location frequency of debit transactions. He said the purpose is to get money in the hands of affected people sooner but he acknowledges the ethical privacy concerns of this practice. He explains that there is a big emphasis on protecting personally identifiable information (PII). He shared that even with Google Street View that when his employer has captured data, they have to go in and “wash out the faces” or other information such as “say a van advertising for an air conditioning service with a phone number.”

Joseph noted several use cases for emerging trends of the intelligent web mapping era. He mentioned that digital twins are very helpful toward planning during hurricanes, windstorms, ice storms, and even big rain events. He noted that FEMA is in the process of mapping all water using elevation and watersheds on a county level for stormwater management and to prepare for weather events. He shared that open data is super important but that big data is hard to share. On how to prepare students to be ready to meet these challenges, Joseph said that their company is looking for well-rounded candidates. He recommended that higher education focuses on remote sensing including classification of LiDAR, understanding the land/water interface, learning how to host services, and learning about data accuracy and survey components. Joseph advises instructors to do demonstrations to “show how cool it is” and get students to “convey thoughts via maps.”

Mara. Mara is a GIS Project Supervisor for an international company that has active contracts in Virginia. Her current role is primarily managing the GIS contract that her employer has with the United States Marine Corps, but in the past, she has worked for the National Geospatial Intelligence Agency and as a locality GIS Manager for an urban city. She does not hold a GISP Certification but does hold the GEOINT Professional Certification, Level 1. Her advice to all GIS professionals is to make sure that GIS has a place at the table when facilities management, purchasing, and procurement decisions are made. She found out the hard way that many legacy systems don’t integrate with GIS and making sure that new systems are compatible is critical to providing support and helping others see the value of GIS. Mara explains that “getting people to understand what GIS can do for you helps them think of their data in a very different way.”

Although her current position is not able to move to many of the emerging trends of the geospatial workforce due to security constraints of the military, Mara shares that she feels the cloud is an important trend that will impact the way most GIS departments operate soon. She also feels big data dashboards, power business intelligence, visualizations, Python programming, imagery analysis, classification, and data-driven decision-making are important geospatial trends. Mara advises geospatial professors to teach the foundations such as basic remote sensing, how to manipulate data, and projections. She relates an example of sharing a template with her colleagues at Camp Pendleton and having to explain to them that they had to change the projections because the projection she used for mapping Virginia would not work for mapping California. Mara thought that this was something that she should not have to explain to a GIS professional no matter what state they are mapping.

State Government Case Study

Benjamin. Benjamin understands many facets of the geospatial workforce, having served in multiple roles, He has worked in state government GIS, as a private industry GIS leader, as a geospatial educator, and providing GIS for a planning district commission. Benjamin is currently a state government GIS Data Services manager. He has 25 years of experience in GIS and 1 year of experience in his current role. He is a GISP and values industry certification as a way for employers to make sure they are getting a qualified person. He also highly values the role of professional organizations as a means to share best practices having served as the President of a professional geospatial organization.

Benjamin’s wealth of knowledge is also a source of frustration for him. He understands the potential of emerging technologies especially machine learning and mobile GIS but works for an agency that has been slow to fully embrace geospatial technology. He mentions that other departments in his agency are using LiDAR, applying GIS to historical preservation, and are beginning to implement sensors that could lead to real-time data collection in the future. Unfortunately, his agency does not currently have agency-wide coordination of GIS so these efforts are in effect silos. He mentioned multiple examples in his department of functions that are currently not utilizing GIS technology effectively that could benefit from GIS implementation. Benjamin is committed to investing the time and effort needed and has a vision for how to lead his agency to embrace emerging GIS technology starting with mobile GIS for fieldwork.

As an educator and employer, Benjamin has insight into curriculum development and provided great detail on what he covers in his introductory GIS classes. He explains that "the concept of what a geographic information system is seems simple but may not be as simple as you might think" and this should be part of the foundational concepts covered. These foundational concepts that should be covered in Introductory GIS classes include understanding projections, scale, file formats, digitization, geoprocessing, database management, editing, how to find data, using spreadsheet and XY data, and a basic introduction to Python.

He also mentioned how important the concept of projection of the fly is to modern GIS and how students are not aware of how difficult GIS was before this was available. According to Benjamin "When projection on the fly came along it changed everything. We take it for granted now. I feel in those days it was much harder for a new person to truly break into the field. I'm not going to say it is easy now, but there is more going on behind the scenes." For advanced GIS curriculum, Benjamin recommends that web mapping, mobile GIS, and machine learning are important emerging geospatial technologies that should be addressed. He contends that "there's another geospatial revolution coming, I think some of this machine learning stuff – ESRI is starting to pull more" in that direction.

Anna. Anna uses GIS for renewable energy "to locate valuable mineral resources and to keep people safe from natural disasters." In her role in state government GIS, Anna leads a GIS-related energy communications program for her agency. She has been in the geospatial profession for 14 years and is mostly self-taught on the job. She holds a Master's degree as a Geologist, but is not a GISP and has no formal education in GIS. She values state agency user group meetings for sharing best practices. She would like to learn more about predictive modeling because of the geospatial applications for solar energy which is very relevant to her current work.

Anna's agency has collaborated with higher education through grants. One example is a Memorandum of Understanding (MOU) with Virginia Tech to do statistical mathematical geospatial visualizations for business intelligence. She shared that through a USGS program, her agency has also collaborated with the College of William and Mary and James Madison University to update data sets. She shares that state agency staff do not always have time to do in-depth work with data sets and that these collaborations with higher education benefit the students, the agency, and the public. She advises that higher education geospatial programs should emphasize open-ended projects, solving problems, and where to find data/resources. She believes that crowdsourcing, data collection, and artificial intelligence/machine learning should be included in Advanced GIS education. From her perspective, the important trends affecting both geology and renewable energy are cloud computing, LiDAR, Imagery, UAVs, sustainability/climate applications, and disaster mitigation (emergency management).

Anna's agency is in the process of updating geological digital maps to be a web service so it can be used as a base map. Anna uses LiDAR extensively for the identification of sinkholes, landslides, karst (sinking streams), mudslides, and landslides. She shares that the future of energy sources is shifting from coal to renewable energy and that GIS plays a role in health and safety, underground mapping, and to "locate valuable mineral resources that are increasingly important in the renewable energy industry as the raw ingredients for solar panels and electric vehicles, not to mention aggregate that builds all the roads and infrastructure."

Abraham. Abraham is a state government GIS Program manager. He has 20 years of GIS experience and 8 years in his current role. He is not a GISP but holds GIS certification in

GIS Specialist for Wildfire (GISS). When asked what skills entry-level employees should have when entering the geospatial workforce, Abraham reflected and shared the example of an intern that he tasked with the simple task of creating a customized story map that took a month to complete. “The templates fit 80% of the public, but we want the 99% right, students need to be able to say oh yeah I can do that.” He describes the four pillars of GIS as cartography, modeling, analysis, and programming. He advises educators to develop proficiency in all of these areas and make sure students can figure out how to problem-solve.

Abraham shares some interesting applications of GIS technology trends including imagery analysis of agriculture to determine fire-resistant plants and analysis to see what survives a fire and what doesn’t survive. In addition, he shares that drones and UAV technology have been useful in GIS analysis for fire management. He shares that conservation programs at his agency are moving toward using GIS in the field with applications such as Collector and mobile mapping in the field. Orthophotography and temporal-spatial analysis account for about 80% of his agency’s GIS needs. Abraham would like to learn Python to be able to customize a dashboard for his agency to share some of the great mapping products that are developed including harvest inspections, forest health observations, water quality inspections, forest conservation, urban canopy, and gypsy moth tracking. He also mentions that there are approximately 10 GIS power users in the agency that have utilized web mapping for urban tree mapping and mapping of damage after hurricane events. He explains that the most important GIS trend affecting his agency is the shift to an Enterprise GIS system allowing users all across the state to see the same information, create and share data, and eliminate data silos in the agency.

Local Government Case Study

Zachary. Zachary took his first GIS course at John Hopkins University in 2001 and was "hooked on GIS from my first attribute join." He shares that 17 years later, as a GIS analyst for a large urban county in Northern Virginia, there are still relatively few GIS analysts that have a raster or imagery background. He recommends that understanding foundational concepts such as coordinate systems, database models, derived slope, and sequel server or Oracle are skills that make a candidate more marketable and a stronger analyst. He shares that everything is moving to web processing so understanding databases, servers, and rest services are critical skills. He also recommends soft skills such as communication and presentation skills and knowing "what's going on behind the scenes" such as scripting, especially with Python. Zachary's recommendations for preparation for geospatial employment come not only from his current role managing remote sensing resources and online portal management, but also from his past experience at the forest service, in landscape architecture, environmental consulting, and top-secret work for the National Geospatial Intelligence Agency.

Although drones are not realistic or practical for his county due to extensive restricted airspace, he believes that in other localities there could be benefits to this technology. Imagery, oblique imagery, LiDAR, and satellite data have been implemented extensively in his county with exciting applications such as fire safety, 3D LiDAR viewer, skinned 3D models of buildings and trees, and planning and development analysis for new building projects. Very detailed analysis is possible through USGS Quality Level One LiDAR data collected with eight points per square meter. While all localities in Virginia have LiDAR data collected, most localities do not have this level of accuracy.

Standards that define accuracy, as well as attribute and domain level standards for consistency and metadata for documentation, are a priority when utilizing both remote sensing data and mapping data collected by county departments. Zachary adds that ethics are important in GIS and that to obtain the GISP certification which he holds, you are signing a document that you understand this professional obligation.

Silas. Silas is a local government GIS Coordinator for a large urban city in Tidewater Virginia. In his current role, he has 23 years of experience finding geospatial solutions to urban problems. He is a GISP and holds a Master's Degree. Silas shared that flooding and the military presence are challenges that often inform his decisions. For instance, UAV technology is not currently an option due to the fact 90% of the city is in a no-fly zone due to the military. Conversely, flooding has enabled the use of emerging geospatial trends in the city such as sensors to collect real-time water level data for flood level prediction and forecasts based on 3D web mapping.

Silas values open data and has developed an open data portal with many data layers downloadable to the public through this central repository of data. This portal includes many valuable data sets such as aerial and oblique imagery which the city captures every year and LiDAR data which is collected every five years. The aerial and oblique imagery is used for vegetation analysis, tree surveys, land use, land cover, and environmental purposes. The LiDAR is used for wind, erosion, sediment shift, parcels, and planimetric. These ancillary layers are also shared on the portal. With all of this data to share with the public, Silas explained that interoperability, communication, and education are obstacles that are still a challenge. Silas explains that the city is moving more and more into Oracle database services. He revealed that he shrewdly used redundancy and the fallout of services being down from patches as a justification for hosting data services in the cloud.

Silas expects to see more use cases for using artificial intelligence and sees the Internet of Things and sensor technology as the future especially when it becomes cheaper. Silas is a visionary. He has predicted the success of geospatial trends before.

> When I first started, gosh it must have been in the early 2000s, I was on a survey and I told them that one day they would be able to get their survey plats on their phones. And they thought I was crazy. But they do now – I mean they use Survey 123 or Collector and can do everything, all of that stuff now.

Silas values sharing his expertise and has participated in partnerships with Old Dominion University. He has strong feelings about what higher education should be teaching. He shared that geospatial education should be diverse in geospatial knowledge to include both fundamentals such as the capabilities of the database, queries, research, data analysis, and emerging trends such as AI/machine learning, data science, LiDAR, and different kinds of sensors.

Ruth. According to Ruth, it is "unrealistic to expect GIS professionals to know everything about all topics." As a local government GIS Manager for a large urban city in Hampton Roads, Ruth handles many things that she never expected to be part of a GIS manager's job 20 years ago when she got her degree in Geography with an emphasis in GIS. With a constant concern of tidal and flood inundation, Ruth has found that real-time data and visualizations, web mapping, open data, and citizen data collection have become important tasks in her role. Ruth has continued her education to get both a certificate in GIS and a certificate in remote analysis in coastal environments from ODU. She shared that as a working professional, having online options for continuing education to stay current in the GIS field helps, but it is still a big time and financial commitment. She also acknowledges that continued training is necessary and wishes she could provide her staff more training to better understand server architecture and security, server maintenance, web applications, and even coding and automating processes.

Ruth has embraced many of the emerging technologies of the web mapping era in her role. She shared that the fleet management system in the city can show the real-time location of all city vehicles. The city is making plans to monitor snow plowing using this system. In addition, the trash trucks all have a camera that collects photo data of the entire city through public works. Ruth sees tremendous potential for Automated Intelligence by utilizing this data to train the machines to capture issues with manholes, signs, pavement analysis, and blighted areas of the city before they are reported by citizens. She even can see applications for police to use this data to alert them of potential criminal activity. Ruth does understand that there are significant challenges such as hardware, software, and privacy. She explained that there are often unintended consequences to collecting data. The city has a Lime scooter rental service which is connected to GPS. At first, the city was delighted to collect details on how fast the scooters were going, the most popular places, and how they were being utilized until it became a concern that individual riders could be identified by patterns in the data leading to personal safety issues and privacy implications.

Despite all of the exciting emerging geospatial technologies that Ruth is fostering in her city, she is emphatic that geospatial education must teach spatial thinking and spatial relationships as a core foundation of GIS. She believes that location analytics "infiltrates and impacts absolutely everything" and "GIS transcends everybody in society." She also advises educators to have students complete non-scripted projects that require critical thinking, problem-solving, research skills, data collection, and data analysis. The reason for this is that she believes that GIS is evolving into the data science of things in the next five years and these skills will be important for data analytics, automated intelligence, and machine learning.

Q Methodology Results

Following the individual interviews, all interview participants and an additional 29 stakeholders who completed a pre-qualification survey were invited to complete Q methodology online for a total of 41 Q methodology participants. The Q methodology statements in the Q-sample were centered around the themes in the UN Future Trends Report (2020) to determine stakeholder perceptions. Q Methodology uses a correlation matrix and a forced distribution sorting grid with inverted factor analysis. The benefit of the prescriptive forced sorting in the pyramid is that it requires participants to make value judgments by reflecting on their experiences (Wright, 2013). The quasi-normal distribution prevents participants from remaining neutral. As part of the Q methodology, participants also provided answers to open-ended qualitative questions after the sorting which was analyzed using category aggregation, word count data analytics, and direct interpretation. Analysis on Q Methodology in conjunction with the primary data source of interviews was used to construct themes of the shared views of stakeholder perceptions on emerging geospatial drivers and trends that are impacting the geospatial workplace.

Q-Sort Results

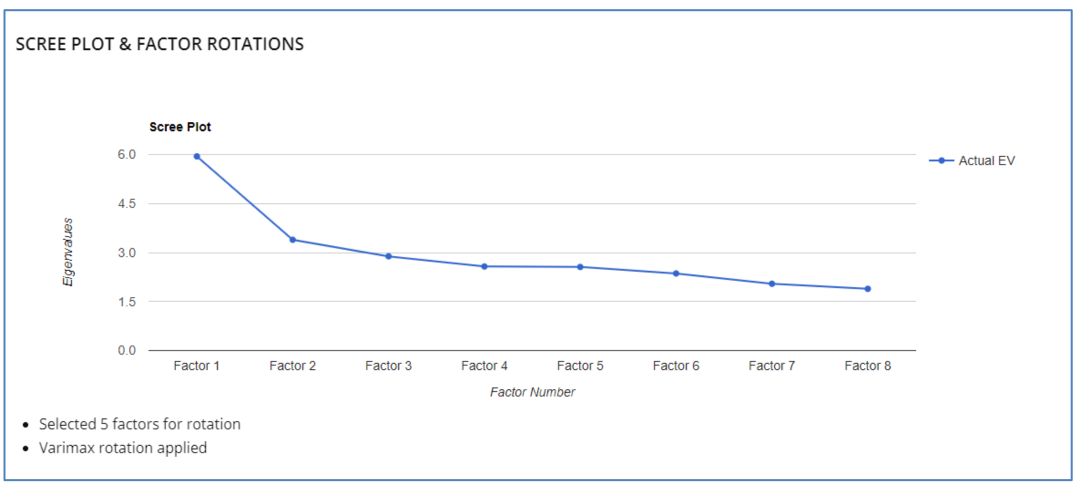
The first type of analysis completed on the Q methodology was the completion of a Pearson correlation matrix. Watts and Stenner (2012) describe this as “the degree of agreement between two sets of scores from the same individuals.” A correlation represented by +1.00 indicates a high level of agreement and a correlation represented by -1.00 indicates a high level of disagreement (Bartlett & DeWeese, 2015). For this study, the highest correlation value was .54 between Matthew and Levi who both work as professors at the same university indicating shared views held by respondents. Matthew also correlated highly with Paul, another educator from a different university, with a correlation value of .49. The third significant correlation occurred between Anna, a state agency stakeholder, and Sarah, an industry manager, who has prior experience in state agency GIS management. These two participants correlated highly with a value of .49. All of the highest correlations involved individuals who loaded on Factor 1 indicating that these individuals all held similar viewpoints.

Next, the researcher used centroid factor analysis, a data reduction technique, which helps explain variance in the Q-sort (Wright, 2013). For the Q methodology, participants were asked to rank 45 concourse statements related to their perceptions of geospatial workforce trends. Factor analysis data reduction parses down the data to a summary of characterizing statements indicative of responses that are representative of each factor (Zabala & Pascual, 2016). Watts and Stenner (2012) recommend that one factor is extracted for every 6-8 participant Q-sorts. In this study, eight principal components (factors) were initially extracted.

Eigenvalues (EV) are special scalars or nonzero characteristic values associated with a linear transformation (Ferrar, 1971). They are calculated by the sum of the squared loadings of all the Q-sorts on a factor. Factors that have an eigenvalue greater than one (1.00) are considered significant and can be analyzed (Dziopa & Aheren, 2011). Initially, eight groups or factors were revealed that collectively characterize the perspectives of the participants in that group. These factors were analyzed to discover similarities and differences between the groups. Eight factors met the criterion of having an EV of 1.0 or greater. Factors 1-5 had an EV of 2.5 or higher. Factors 6-8 were eliminated due to EV below 2.5 (Simons, 2013). Additionally, one of the five factors that met the criteria of an EV of 2.5 or greater was eliminated by the researcher based on rationale by Brown (1980) which states that a factor should only be included in the analysis if at least two or more participants load on that factor. In this case, only two participants loaded on this factor so it was eliminated. The remaining factors which were included in the study had at least six participants that loaded on each factor. Participants were considered to load on a factor with a $p < 0.05$, but to be significant with 45 statements, the loadings needed to be +/- .27. Factor rotation which attempts to demonstrate the best combination of variable relationships is another step in the data analysis for Q Methodology. Varimax rotation was applied by the researcher which is the appropriate factor rotation method for exploratory research (Cuppen et al., 2016; Wright, 2013). The researcher also used a scree plot to provide a visualization of the factors which supported the decisions to eliminate factors. Therefore, based on the raw data and analysis, Figure 4.1 reinforces a 4-factor solution was deemed the most appropriate fit.

Figure 4.1

Scree Plot and Factor Rotations



Each extracted factor has unique characteristics (Table 4.4) such as the number of participant Q-sorts that loaded on that factor (number of defining variables), the average reliability coefficient, composite reliability, and standard error (SE) of factor Z scores. The average reliability coefficient is the expected level of correlation between responses given by the same person in Q-methodology is customarily a value of 0.8 (Zabala & Pascual, 2016). Composite reliability over 0.8 is an indication of a factor's strength. In this study, each of the factors extracted and included in the study have composite reliability of at least 0.96. The standard error of factor Z-scores is calculated as 1/(√ number if items in the Q-sample) (Wats and Stenner, 2012). For this study the formula is as follows: SE = 1/(√ 45); SE= 1/(6.708); SE= 0.15. The two highest loadings on each factor must correlate at a level that exceeds this standard error. Each of the extracted factors has a standard error Z score that exceeds the standard error of 0.15 and therefore is acceptable.

Table 4.4

Factor Characteristics

Factor Characteristics	Factor 1	Factor 2	Factor 3	Factor 4
No. of Defining Variables	7	7	6	6
Avg. Rel. Coefficient	0.8	0.8	0.8	0.8
Composite Reliability	0.96552	0.96552	0.96	0.96
S.E of Factor Z-Scores	0.1857	0.1857	0.2	0.2

The purpose of factor analysis is to reveal the patterns in the data based on participants who have shared perceptions and beliefs and therefore responded by similarly ranking the Q-sort statements (Zabala & Pascual, 2016). Participants who load on one factor have commonalities that differentiate them from participants who load on the other factors (Valenta & Wigger, 1997). Adding to this concept, Van Excel and de Graff (2005) explain that "a factor loading is determined for each Q-sort, expressing the extent to which each Q-sort is associated with each factor" (p.8). The Q-sorts that load on a particular factor are flagged to reflect the viewpoint of that factor. After sort flagging, the researcher analyzed the factor array which is a clustering of similar Q-sorts to create a composite Q-sort. The composite Q-sort reflects the statements that are collectively most representative of the participants that loaded on that factor. As Cuppen et al., (2016) notes, the factor array is a strength of Q methodology. It aids the researcher in interpreting the statement rankings in each factor and helps the researcher to develop themes (Bartlett & DeWeese, 2015). Each participant sorted and ranked the statements about their perceptions of the importance of emerging geospatial trends using a scale ranging from “most relevant trend” (+5) to “least relevant trend” (-5). For each factor, the highest and lowest statements (z-scores) are the anchor statements as seen in Tables 4.5 and 4.6.

Table 4.5

Highest Ranking Statement for Each Factor

Statement	Factor	Z-Score
(45) Geospatial role in Developing a Sustainable Future	1	1.8168
(15) Cloud Computing and SAAS	2	2.2092
(17) Open Geospatial Data Services/Portals	3	2.0637
(31) Sector Skills Training	4	2.7080

Table 4.6

Lowest Ranking Statement for Each Factor

Statement	Factor	Z-Score
(14) Edge Computing and the Semantic Web	1	-1.9327
(36) Open Source Geospatial Software	2	-1.7498
(21) Mapping the Ocean/Bathymetry	3	-1.9754
(30) Increased Diversity in the Geospatial Workforce	4	-1.8858

Consensus statements are consistent across all of the extracted factors (Van Excel & de Graf, 2005). In this study, the researcher identified two consensus statements. Statement 37 (Increased demand for 3D modeling/visualizations) was ranked consistently positive and as very relevant on three of the four factors. Data creation from social media platforms using a smartphone (statement 10) was ranked consistently negative and as very low relevance by three of the four factors.

The primary data source of interviews was used to determine themes. Factor loading data were analyzed to reveal if they confirm or refute the findings of the interview themes. Several Q Methodology participants loaded on more than one factor. Also, four Q Methodology participants did not load on any of the four extracted factors. In these cases, the open-ended questions were analyzed in addition to the factor loadings to determine which theme was the best fit for the participant.

Open-Ended Question Results

Participants were asked to answer qualitative questions about their perceptions and sorting choices after completing the Q methodology. Participants were asked to explain the reason for their selection of the trend for the most relevant (+5) and least relevant (-5) position in their Q-sort. Next, they were asked if they had trouble placing any statements and why. They were asked what factors helped determine the sorting order. Respondents were asked which trends are relevant to their current work. They were asked to describe professional development they would like to receive based on the trends included in the Q-sort. Respondents were asked which trends should be included in a curriculum for Advanced GIS in higher education and why. Finally, they were asked for any additional thoughts not covered by previous questions. The open-ended questions in the Q methodology were analyzed for each case and across the cases to reveal the patterns. Coding and pattern analysis revealed several interesting patterns in the data collected.

Table 4.7 shows the word count data analytics based on the number of mentions of a trend in the open-ended questions. Mentions in the responses about negative viewpoints toward trends were excluded from this table. This table only represents positive or neutral sentiment mentioned in the responses to questions.

Table 4.7

Trend Mention Word Counts in Open-Ended Questions

Trend/Key Phrase	SG	LG	Academia	Industry
(2) Data Digital Infrastructure/IOT	3	3	5	0
(3) Intelligent Mobility	0	0	0	4
(5) Digital Twins	0	0	0	2
(6) Data Standards	3	0	0	0
(7) Big Data and Data Analytics	6	4	6	3
(8) Automated Intelligence/Machine Learning	6	5	14	5
(11) Data Integration	5	0	8	4
(12) Mission Ready Data	5	0	0	2
(13) Linked Data	6	2	2	3
(15) Cloud Computing and SAAS	2	2	11	0
(16) High-Resolution Satellite Technology	0	0	3	0
(17) Open Geospatial Data Sources/Portals	4	4	6	5
(18) Unmanned Aerial Vehicles/Drones	3	0	14	2
(19) Integrated Smart City Solutions	0	0	0	2
(23) Renewable Energy	2	0	2	2
(24) Digital Rights Management	0	0	4	0
(25) Digital Ethics/Privacy/Cybersecurity	1	0	4	0
(28) Inclusion of GIS in K-12	2	0	3	2
(29) Reskilling/Upskilling Workforce	0	0	3	3
(30) Diversity in the Workforce	0	0	0	2
(32) Open Geospatial Science	4	0	2	2
(33) Networking/Sharing Best Practices	2	0	2	0
(36) Open Source Geospatial Software	4	4	0	0
(37) 3D Modeling/Visualizations	2	2	0	2
(43) Value of LiDAR Data	0	9	3	0
(44) Geospatial Emergency Management	4	4	2	3
(45) Sustainability/Climate Change	4	0	0	5

Document Analysis Results

*DOLETA GTCM and O*NET Documentation Review Results*

The DOLETA GTCM identifies core geospatial areas of knowledge and abilities and identified competencies to align higher education curriculum to workforce needs (DiBiase et al., 2010). Tiers 1-3 of the DOLETA GTCM specify the personal effectiveness competencies, academic competencies, and workplace competencies which are collectively considered foundational. Tier 4 lists crosscutting geospatial abilities and knowledge that are industry-wide skills. Tier 5 lists three industry sector-specific skills for specialization – positioning and data acquisition, analysis and modeling, and software application and development. Tiers 6-8 are occupational-specific requirements for occupations published in the Department of Labor's O*NET occupational database (O*Net, 2022). Tier 9 of the GTCM reflects geospatial management competencies that characterize successful geospatial management. See Appendix G for the structure of the competencies as provided by DOLETA for the Geospatial Technology Competency Model.

A review of the O*NET geospatial occupations (onetonline.org) revealed that no new GIS-specific occupations have been added since 2009, although a few have been slightly re-named or combined. Table 4.8 presents both the historical (2008 US outlook data listed in the DiBiase (2010) study) and current US and VA O*NET outlook data for those occupations to show how they have changed over time. Most research studies cite DiBiase's 2008 statistics from this study and do not investigate how career tracks have dramatically changed in the past fourteen years.

Table 4.8

*Geospatial Occupations Defined by the DOLETA O*NET*

Occupation listed in O*NET	**US Employment (2008)**	**US Employment (2020)**	**Virginia Employment (2018)**	**Virginia Projected growth rate (2020-2030)**
Geographic Information Systems Technologists and Technicians	209,000	442,200	16,020	9%
Cartographers and Photogrammetrists	12,000	13,200	510	20%
Remote Sensing Scientists and Technologists	27,000	23,900	1,850	4%
Remote Sensing Technicians	65,000	69,700	1,860	5%

Precision Agriculture Technicians	65,000	26,600	1,860	5%
Geodetic Surveyors	58,000	46,000	1,640	4%
Surveying and Mapping Technicians	77,000	54,800	2,130	6%
Totals	513,000	676,400	25,870	N/A

A simple search of Indeed.com (the largest online job search website) with GIS in the search box revealed 454 GIS-related jobs in Virginia. Table 4.9 demonstrates a snapshot of the GIS career outlook aggregated by job title in Virginia in January 2022 (Indeed, 2022). The Indeed.com website only shows results within the past 30 days. GIS Analyst is the most prevalent job title found on this search with 155 job openings for this role in the past 30 days in Virginia. This job title is not listed in O*Net indicating a gap in knowledge between O*NET and the geospatial workforce.

Table 4.9

Geospatial Job Opening listed on Indeed.com by Aggregated Job Title in Virginia (Jan. 2022)

GIS Mgmt	**Mid-Level**	**Entry-Level**	**IT related**	**Other**
Manager: 56 Director: 18 Coordinator: 4 Administrator: 5 Educator: 6 Scientist: 12 Consultant: 7	Analyst: 155 Planning: 29 Surveying: 6 Researcher: 9 UAS: 2 Specialist: 34 Photogrammetry:6	Cartographer: 3 Technician: 12 Bus. Support: 9	Engineering: 33 Developer: 17 Programmer: 2 Enterprise: 4 Tech Solutions:9 Architect: 2	Biologist: 2 Conservation: 2 Sustainability: 1 Forestry: 3 GEOINT:51 Geologist:1

Virginia College and University Offerings Results

Lastly, a document review was completed using records provided by Virginia colleges and university websites. College catalogs and course offerings were reviewed to compare which colleges and universities offer GIS degree programs, GIS certificate programs, and GIS course offerings. Also, the registrar at each college or university was emailed to verify and confirm the online findings. Additionally, GIS programs and collaborations between institutions and state agencies were investigated. This data sheds a light on the current status of GIS education in the Commonwealth of Virginia and to what degree stakeholder perceptions of what is needed to prepare students for the geospatial workforce are already being met. It also identified what gaps still exist between expectations of the workforce and the current education curriculum.

Virginia Tech and George Mason University offer the most options for students in GIS and remote sensing and are the only two universities in Virginia that offer PhDs in Geographic Information Systems. Virginia Tech, George Mason, and the University of Mary Washington offer Master's Degrees in GIS. Several universities offer Bachelor’s degrees in GIS – George Mason, James Madison University, Radford University, and Virginia Tech. All of these are public universities. No private colleges or universities offer degree programs in GIS or remote sensing in the Commonwealth of Virginia.

Undergraduate Certificates in GIS are offered by George Mason, Old Dominion, Radford, and Mary Washington. Graduate Certificates are offered by William and Mary, George Mason, Old Dominion, Virginia Commonwealth University, and Virginia Tech. No private colleges or universities in Virginia offer a certificate program for credit. One private college, the University of Richmond, offers a non-credit GIS certificate through their workforce program.

GIS minors are offered by George Mason, Longwood, Virginia Tech, and Bridgewater College. All public four-year colleges and universities in Virginia offer at least one GIS class except Norfolk State University. Of the HSCUs in Virginia, only Virginia State University offers a GIS course. The following private colleges and universities in Virginia offer at least one GIS course – Bridgewater, Emory & Henry, Ferrum, Hollins, University of Lynchburg, Liberty University, Randolph Mason College, Roanoke College, Shenandoah University, University of Richmond, Virginia Wesleyan University, and Eastern Mennonite College.

The emphasis on Coastal Resiliency and Flood Inundation research in the Commonwealth of Virginia is evident in that three public universities in the state have developed Centers dedicated to this issue. Virginia Tech has a Center for Coastal Studies (VT, 2021), the University of Virginia has a Coastal Research Center (UVA, 2021) and Old Dominion University has an Institute for Coastal Adaptation and Resilience (ODU, 2021). In addition, Virginia Tech has several active GIS partnerships with state agencies. Virginia Tech is collaborating with VDOT to perform geospatial analysis of crashes, demographic and related information. Additionally, Virginia Tech is collaborating with VGIN to develop an interactive broadband coverage availability map in Virginia. Previous partnerships with VGIN and academia through the VA Geospatial Archive Resource and Data Exchange Network (GARDEN) initiative no longer appear to be active. Appendix H shows the GIS offerings of Virginia colleges and universities. The triangulation of data collected from individual interviews, Q methodology, and document review was analyzed to provide insight into each of the research questions in this study.

Theme Development

The purpose of this exploratory collective case study was to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia. Analysis of the primary data source of interviews in conjunction with Q Methodology and documentation was used to construct the themes of the shared views of stakeholder perceptions on emerging geospatial drivers and trends that are impacting the geospatial workplace. The researcher used pattern matching and cross-case synthesis to compare the cases as recommended by Yin (2009). The researcher also conducted distinguishing statement analysis, factor extraction analysis, and developed a correlation matrix that summarizes the views of participants to develop the theme narratives. Notetaking, bracketing, member checking, and coding of the data were also utilized by the researcher. The study identified four distinct viewpoints held by geospatial stakeholders in Virginia. These viewpoints are called factors in Q methodology and themes in qualitative research. This study will refer to them as themes. The themes identified are social education, technology early adoption, data collaboration, and urban fundamentals.

Theme 1: Social Education

This theme group demonstrated a clear emphasis on social values and civic responsibility as a key frame of reference for GIS professionals. Participants in this group placed the highest value on the geospatial role in sustainability and societal issues such as climate change (Table 4:10). They were willing to consider emerging technologies, but only if they served a higher purpose such as facilitating emergency management or renewable energy. This group not only values the diversity of thought and backgrounds, but also demographic diversity in the geospatial workplace. They value engagement and collaboration through open geospatial science and sharing resources. They also highly value education including the K-12 geospatial pipeline. The least relevant trend to this group was edge computing and the semantic web.

Table 4.10

Most Characteristic Trends for Social Education Theme

No.	Most Characteristic Trends for Social Education Theme
45	Geospatial role in developing a sustainable future (2030 Agenda for Sustainable Development) - climate change initiatives, environmental concerns, e-economies, demand for natural resources, resource security, pollution, water stress, deforestation, biodiversity loss
18	Unmanned Aerial Vehicles (UAVs/drones) as a viable alternative to conventional mapping for small area surveys
28	Inclusion of geospatial concepts at primary and secondary levels not just higher education.
30	Increased Diversity in the Geospatial Workforce - a mix of ages and experience, cultural background, gender, race, and neuro-diverse skillsets.

44	Emergency management adoption of geospatial based operation models including disaster response (planning, mitigation, response, recovery), police, fire, rescue, and 911 calls
32	Open Geospatial Science (Sharing of resources among the geospatial community) - transparency and evidence-based reproducible workflows in research, sharing lessons learned, innovative collaboration, and publications to allow sharing resources.
27	Geospatial Career Paths have diversified to include many new expert groups such as data science and analytics, computer science, data visualization, etc. in addition to GIS analysts, geographers, surveyors, photogrammetrists, and remote sensing and earth observation scientists.
23	Geospatial Technology Role in Renewable Energy - Solar, Wind, Biomass, Hydropower, Geothermal

The participants who were uniquely associated with this theme included three industry professionals, three from academia, and one state agency stakeholder (Table 4:11). Interestingly, the state agency stakeholder is engaged in renewable resources, one of the defining characteristics of this group. No local government stakeholders loaded on this theme. Social educators perceive that user requirements and education are important for the geospatial workforce to solve societal issues such as climate change. Samson, who falls in this group reflects this group's perspective:

> The geospatial role in addressing social priorities is a very hot topic. I am so glad that GIS is being used to shed some light on the relationships between race, poverty, and location.

Table 4.11

Theme 1 – Social Educators Overview

Participant	Sector	Loading on Factor/Theme
Samson	Industry	.64075
Joel	Industry	.46774
Matthew	Academia	.67545
Levi	Academia	.53518
Sarah	Industry	.72824
Paul	Academia	.57746
Anna	State Agency	.70634

The majority of participants who fall into this group have work applications of the characteristic trends for this theme. Matthew, Levi, and Paul are all engaged in geospatial education and geospatial career paths. Samson, Joel, and Sarah are industry professionals who value open geospatial science, diversity in the geospatial workforce, and the geospatial role in societal issues such as sustainability. Anna is a state agency professional whose role is directly related to renewable energy.

Theme 2: Technology Early Adoption

The technology adoption lifecycle represents a model describing the adoption or acceptance of new technology (Liao, 2009). The participants of the study that loaded on this theme are early adopters of new geospatial technology. The main characteristics of this theme are all related to emerging geospatial technology advancements. Cloud computing and SAAS were the most relevant trend to this group with automated intelligence and machine learning following close behind (Table 4.12). Innovations on the cutting edge of GIS resonated with participants who form this theme group including mobile GIS, ubiquitous connectivity using 5G, big data analytics, infrastructure using sensors, and the Internet of Things (Table 4:13). They also valued data integration which is necessary to do analytics using these technologies. This group recognized that the workforce would need reskilling or upskilling to meet the demands of these technologies. The least relevant trend for this theme is open source geospatial software.

Table 4.12

Most Characteristic Trends for Technology Early Adoption Theme

No.	Most Characteristic Trends for Technology Early Adoption Theme
15	Cloud Computing and Service-Oriented Architecture (Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS))
8	The potential of Artificial Intelligence/Machine Learning Algorithms in Geospatial Production (particularly image analysis and information extraction)

11	Data integration - merged geospatial data for contextualized location-enabled insights to reveal patterns and predict behavior
2	Digital data infrastructure and the Internet of Things (connected sensors in physical infrastructure that collect vast quantities of data accessible online)
34	Making mapping available to the masses - web and mobile mapping changing the volume and type of data consumers and their demands.
1	Ubiquitous connectivity (through the deployment of 5G technology)
7	Realizing the Value of Data through Big Data and Data Analytics (descriptive and predictive analytics)
29	Reskilling and Upskilling of the Geospatial Workforce for higher-value tasks (includes skills transfer and knowledge capture)

It is interesting to note that no industry or state agency stakeholders aligned with this theme. All of the participants in the technology early adaptor theme were either from academia (Job, Matthias, David) or local government (Zachary, Adam, Aaron, Ruth) indicating that academia may understand the technology needs of local government stakeholders better than they understand state government or industry stakeholders (Table 4.13).

Table 4.13

Factor 2 - Technology Early Adoption Overview

Participant	Sector	Loading on Factor/Theme
Job	Academia	.56653
Matthias	Academia	.63377
David	Academia	.44344
Zachary	Local Government	.39702
Adam	Local Government	.65520
Aaron	Local Government	.36406
Ruth	Local Government	.72056

The perception of this group is diametrically opposite of the Social Education group. Job expressed this sentiment “Geospatial role in developing a sustainable future is word salad and aims to address so much it says nothing.” Ruth explains why this group values emerging technological advances:

> Artificial Intelligence and Machine Learning have vast potential in improving workflows, automating time-consuming and expensive data capture and data maintenance tasks,

> identifying patterns, and providing input for better, more informed decision making. While we are only in the early stages of implementation, the long-term potential led me to place this in the +5 column.

This perspective was typical of all participants in this group. Adam placed the highest value on different technological advancements but shared the same mindset in his perception of technology advancement as the most important driver in the geospatial workforce:

> SaaS and Cloud services are without a doubt the fastest growing trends out there. Also, mobile 5G connectivity is the most anticipated trend among data and computing and will certainly impact GIS.

Theme 3: Data Collaborators

Data-centric is a term that would apply to the participants that align with this theme. Most of the characteristic statements for this group center around data collection methods, data collaboration, and use cases for data (Table 4:14). Open geospatial data services and portals ranked as the highest collective priority for this group with the group placing particular importance on LiDAR as a dataset. Mission-ready data and linked statistical data were also important. Data integration was valued. Intelligent mobility such as self-driving car technology was seen as a compelling use case along with more familiar use cases of renewable energy and emergency management. The least relevant trend for this theme is mapping the ocean and bathymetry.

Table 4.14

Most Characteristic Trends for Data Collaboration Theme

No.	Most Characteristic Trends for Data CollaborationTheme
17	Open Geospatial Data Sources/Open Geospatial Data Portals - free and open data sources to provide for analysis with minimal additional user effort and interoperability

12	Mission Ready Data (Accessibility and Discoverability of Data - via portals, APIs, and linked identifiers to enable effective data use)
13	Linked Data (geospatially enabled statistics for social, economic, and environmental issues)
11	Data integration - merged geospatial data for contextualized location-enabled insights to reveal patterns and predict behavior
23	Geospatial Technology Role in Renewable Energy - Solar, Wind, Biomass, Hydropower, Geothermal
3	Interconnecting transport through intelligent mobility (ex. Connected and Automated Vehicles)
43	Increased availability and accessibility of high-resolution point cloud Lidar data.
44	Emergency management adoption of geospatial based operation models including disaster response (planning, mitigation, response, recovery), police, fire, rescue, and 911 calls

This group includes three state agency stakeholders, two industry stakeholders, and one local government stakeholder (Table 4:15). The enormous amount of big data has in many ways formed the intelligent web mapping era. Open geospatial data sources, linked data, and the integration of data to enable insights that reveal patterns are of the greatest importance to Delilah, Diana, and Samuel who are state agency GIS managers. Joseph and Jesse are industry stakeholders who utilize remote sensing data and mission-ready data for their clients. Philip is a planning district commission GIS stakeholder who serves as the GIS manager for multiple localities and recognizes the value of data for emergency management.

Table 4.15

Factor 3- Data Collaborators Overview

Participant	Sector	Loading on Factor/Theme
Delilah	State Agency	.62813
Diana	State Agency	.52713
Samuel	State Agency	.44415
Philip	Local	.45538
Joseph	Government	.61891
Jesse	Industry	.50176

Intelligent web mapping is by its nature a way of collaboration and sharing remotely to develop data-driven solutions. Diana sums up this perspective:

> Our team has had a big focus on mission-ready data including data structure, standardization, and sharing methods over the past two years. Employees and outside clients are becoming tech and data-savvy enough to recognize the analytical potential of the massive amounts of information we have access to, but planning and executing the work needed to make the data ready and accessible is overwhelming.

Philip shares “Online and particularly mobile mapping is the present and near future. We can push out more user-friendly apps and platforms that enable other people to use GIS, but not need an in-depth education in GIS.” Delilah explains that “using big data for predictive modeling and performance measures is a trend in my current job in transportation.” This group recognizes the value of data and collaboration to succeed in the geospatial workforce.

Theme 4: Urban Fundamentals

GIS fundamentals and solving urban problems were priority number one for participants located in Virginia’s cities. These stakeholders are well-rounded and value all of the drivers, with a trend from each of the drivers listed on the most characteristic trends for the Urban Fundamentals theme (Table 4.16). The highest value trend for participants aligning with this theme was sector skills training which is a practical approach to obtaining the needed specialized skills to solve unique urban problems. These stakeholders place importance on structure, organization and order, and place a high value on standards and ethics. Interview questions and open-ended questions revealed that urban stakeholders seek efficient solutions to urban problems such as digital twins and small area data collection using UAV drone technology. The least relevant trend for this theme was increased diversity in the geospatial workforce.

Table 4.16

Most Characteristic Trends for Urban Fundamentals Theme

No.	Most Characteristic Trends for Urban Fundamentals Theme
31	Sector Skills Training - addressing the short-term needs of a geo-information sector with occupational skills needed for the workforce through professional development/training.
6	Developing Data Standards for data creation and maintenance (addressing data interoperability, compatibility, format, quality assurance)
43	Increased availability and accessibility of high-resolution point cloud Lidar data.
25	Digital ethics/ Data Privacy/Cybersecurity addressed by national and international initiatives. Ethical and responsible use of geospatial applications.
32	Open Geospatial Science (Sharing of resources among the geospatial community) - transparency and evidence-based reproducible workflows in research, sharing lessons learned, innovative collaboration, and publications to allow sharing resources.
18	Unmanned Aerial Vehicles (UAVs/drones) as a viable alternative to conventional mapping for small area surveys
2	Digital data infrastructure and the Internet of Things (connected sensors in physical infrastructure that collect vast quantities of data accessible online)
5	Digital Twins for modeling, simulation, and prediction. (In comparison to static 3D models, digital twins are directly linked to multiple data sources and receive updates continuously)

All but one of the stakeholders in this Urban Fundamentals theme are located in large urban areas with Deborah and Timothy from Richmond and Martha, Silas, and Tabitha from Tidewater. Joanna is from a small urban area in Southwest Virginia (Table 4.17). These stakeholders appreciate the practicality of focusing on the fundamentals, sharing best practices through open geospatial science, and are invested in using proven GIS that builds on the basics such as LiDAR data and sensor technology.

Table 4.17

Factor 1 – Urban Fundamentals Overview

Participant	Sector	Loading on Factor/Theme
Deborah	State Agency	.32174
Martha	Local Government	.44269
Silas	Local Government	.48967
Tabitha	Academia	.40353
Joanna	Local Government	.66976
Timothy	State Agency	.59020

These stakeholders place a high value on GIS solutions to urban problems such as Deborah who wants to “know how to set up Hub and Portals, register services, and provide dashboards” which are typical smart city solutions for sharing data. Joanna, although from a smaller city, is very engaged in the geospatial community. She reflects her value for sharing resources among the geospatial community “end-users and developers of data can collaborate during networking groups to develop best practices.” Structure, standards, and ethics were also valued by this group as expressed by Tabitha:

> I can see the importance of sharing data among communities and the open geospatial capability. However, it adds so many uncertainties e.g., how to control data quality, which data standards to use among communities and how to protect confidential data.

Outlier Data and Findings

One finding was unexpected but would not be categorized as an outlier. Diversity in the geospatial workforce was listed as the most difficult trend to place on the pyramid by 12% of participants. Although that is not a very high percentage, it was the most frequent answer for this question. Stakeholder perception of the trend of increased diversity in the workforce was not-conclusive. On the not relevant side, four respondents placed it at the least relevant trend (-5) position on the pyramid with one additional participant placing it at (-4). Conversely, only one participant placed it as the most relevant trend (+5) and four additional participants ranked it as (+4). No other trend showed this much variance in ranking. This finding is interesting and troubling.

Li (2020) reports that in the United States 75% of all GISPs are male. The Li study reports that Virginia also has a 70-75% male GISP rate. Additionally, documentation review reveals that only one HBCU in Virginia offers a GIS course, and none offer degree programs in

GIS. This does not bode well for increasing diversity among Virginia GIS stakeholders in leadership positions. A notable explanation given by 61% of respondents in the study was that they placed trends that are relevant to their experience on the positive section of the pyramid and trends that do not directly affect them or they don't understand in negative positions on the pyramid. The researcher interprets that the non-conclusive finding on the diversity in the workforce trend reflects that many participants did not view this trend as directly affecting them (68% of study participants are white males), while an equal number of participants (particularly women stakeholders) also either perceived it as important or very relevant to their experiences. Additional research is needed to investigate this finding.

Research Question Responses

Central Research Question

The central research question for this study is: *How do educators, state government mangers, local government managers, and industry stakeholders perceive the emerging geospatial drivers and trends that are impacting the geospatial workplace?* Stakeholders from all four case studies agreed that the emerging geospatial drivers and trends listed in the United Nations Future Trends Report (2020) are important impacts to the geospatial workforce. Abraham, who is a state agency GIS manager sums up one common perception of stakeholders in the study with his comment "You know, I love the career that we've chosen." It is noteworthy that although all stakeholders in the study greatly value the power of GIS, there are varying perceptions among stakeholders on which geospatial drivers and trends are most relevant. David, who is in academia, gave his viewpoint on stakeholder perceptions of geospatial trends: "I have a global perspective. Geospatial issues that are emerging in other countries may or may not be emerging in the US." Four common themes emerged regarding how stakeholders perceive geospatial workforce drivers and trends impacting the geospatial workforce. These themes were social education, technology early adoption, data collaboration, and urban fundamentals.

Sub Research Question 1

The first sub-research question for this study was: *How do geospatial stakeholders describe emerging technological advancements in the geospatial workforce?* Stakeholders from all four cases agreed that technological advances were important trends in preparing students for the geospatial workforce. However, there were varying perceptions on which technological trends were important and the degree of the importance of these trends. There are seven trends for the technological advancements driver including ubiquitous connectivity, cloud computing, and service-oriented architecture, digital twins, geospatial internet of things, intelligent transport systems and edge computing, artificial intelligence and machine learning, and geospatial visualizations and immersive 3D environment technology.

There were contrasting viewpoints on digital twins. Only industry stakeholders mentioned this trend in the open-ended questions but two of the industry stakeholders that did so have polar opposite viewpoints. Samson shares that “with climate change and other growing challenges, having a digital twin to see the different scenarios that can be modeled before actually doing so can help inform policy.” Reuben shared that “digital twins feel like a trend.”

Although Simon (industry) believes that GIS will become more integrated into virtual reality, most stakeholders did not place a high value on this technology with no positive mentions in the open-ended questions. One example of a negative mention was by Luke, in academia, who stated “Honestly, I think virtual reality and augmented reality is a joke. This technology is not advanced enough to make it useful and I have a hard time seeing the use case for it.” Artificial intelligence and machine learning on the other hand was valued greatly by all stakeholder groups with this being the highest valued trend by academia stakeholders (14 mentions) and the most mentioned trend overall by all cases in the interviews and open-ended questions. Zachary, a local government stakeholder, explains that "Deep learning and Python to automate imagery classification and object detection – I believe these trends will become more important as data volume increases."

The technology early adaptor theme group valued not only AI and machine learning but also highly valued cloud computing and IoT. Cloud computing was mentioned in the interviews and open-ended questions by three of the four stakeholder groups. It was the second most important trend to academia (11 mentions) but was not mentioned by industry stakeholders. Matthias related that cloud computing is desirable but not realistic for academia because "it's a paycheck you have to write every month and you just can't guarantee how much it costs every month, usage goes up and down" so it isn't practical from a budget standpoint. Zachary, another stakeholder from academia, felt it was worth the cost, stating that "cloud computing is changing the way that GIS is implemented and delivered to end-users as a platform for analysis and decision support." The geospatial IoT was also mentioned by all groups except industry in the open-ended questions; however, industry did value this trend in the interviews and Q methodology sorting.

David (academia) sees the interconnectedness of many of these technologies as critical "sensors in general and the network that is required to support all of this (including IoT and 5G) is increasingly relevant." This is particularly true for urban environments. Three-dimensional modeling and visualizations of 3D data were valued as an important trend by the majority of stakeholders. Benjamin, a state agency stakeholder, shares "Modeling is very relevant to my current work due to the fact that we work with a significant amount of environmental data that is ripe for modeling."

Simon was the lone stakeholder who ranked transport and mobility solutions as the highest value priority. Although other Virginia stakeholders disagreed, his viewpoint aligns with the United Nations that this is an important trend. Simon says:

> The utility of geospatial data will explode as it drives transport and mobility solutions through interconnected solutions; increasing the safety and efficiency of travel will make life better for the entire planet.

Quantum computing was another technological advancement that did not resonate with stakeholders but that the United Nations experts regarded highly for its future potential for intensive processing of geospatial data. Currently, this technology is not yet operational for real-world geospatial applications. For that reason, it was included in the Q-sort but not in the relevant trends analyzed in the interviews. Quantum computing remains an intriguing future trend, however, it was not valued by Virginia stakeholders. Anna, a state agency manager stated "I am not grasping how physics and GIS are related."

Sub Research Question 2

The second sub research question for this study was: *How do geospatial stakeholders perceive the rise of new data sources and analytical methods in the geospatial workforce?* The trends under the rise of new data sources and analytical methods requirements driver are big data and data analytics, remote sensing data, linked data, social media data, crowdsourced and volunteered geographic information, and data integration and interoperability. The lack of available data in the 1990s and early 2000s is what led the geospatial industry to focus on data collection. Now the opposite of this is true, data are abundant from an array of public and private sources, and the industry is now focused on data analysis which David correctly pointed out is, therefore "exceedingly complex." The result is the need to process big datasets which has led state agency and academia stakeholders in this study to recognize the value of data science and using automated intelligence/machine learning especially related to the analysis of remote sensing data such as imagery and LiDAR. Many GIS professionals still don't fully understand the value of this data or use it to its full potential. Joseph, an industry GIS manager explains:

> You know people don't understand that they might have a dataset that can give them that information. This sad realization all the time when we deliver LiDAR data that you know the million points are collected on a tile and only 10% of them are ground points that get dumbed down, so now you're talking like 80% or more of the data that I collected just doesn't get used. You know we got to give people the ability to have that in their hands, and then they can try to understand that they can get a tree canopy and then get buildings, they get all that data that's lost when you are just producing a digital elevation model so that kind of goes into the education component – how do we get people trained?

A local government perspective confirms that Joseph's sentiments are grounded in reality. Aaron, a local government planning department manager, shares "larger datasets, global matters, and visual representations have less 'concrete' relation and are less useful." Participants also highlighted new data collection methods in their responses. David, who works in academia, shared "I view small area UAS as the frontier to support many applications, ranging from conservation management to precision agriculture."

Sub Research Question 3

The third sub research question for this study was: *How do geospatial stakeholders describe the evolution of user requirements?* The trends under the evolution of user requirements driver include digital natives, digital divide and exclusion, demand for real-time data provision, and emphasis on the urban environment and smart city solutions. The trends under this driver ranked highly among many participants especially for those that were part of the social educator theme group. Gabriel (state government) explains that user experience is very user-specific "Although functionality should remain largely equivalent, I don't feel there should be an expectation for identical user experience."

In the open-ended questions, all stakeholder groups expressed value for the use of GIS in emergency management with the state and local government cases placing a higher value on this trend than the other two cases. This may be partially attributed to a legislative emphasis on coastal inundation and recurrent flooding research in Virginia affecting several state agencies. Additionally, the current push for Virginia to move to Next Generation 9-1-1 services and FEMA's stormwater management planning impacts all Virginia localities.

The consensus among the social education theme group is that sustainable initiatives, climate change, and the renewable energy sector are critical issues for GIS education to address. Local government was less interested in these trends with no stakeholders from local government having viewpoints aligning with the social education theme. Samson, an industry stakeholder, explains why he values the geospatial role in developing a sustainable future "by empowering younger generations with this information early on they have the opportunity to learn more and make a bigger difference." Reuben (industry) explains that "climate change is the biggest impact from GIS I have seen in this area." In regards to the Q-sort, he provided feedback "I would have expected more on climate change."

The state government case found value in renewable energy. Samuel, who works as a conservation manager, noted that he is mindful of site issues for renewable energy projects.

Anna, another state agency stakeholder, gave her viewpoint on why renewable energy is an important trend:

> It's very important to locate your resources, so you don't sterilize a resource by say paving over a world-class deposit of kyanite because you didn't know it was there and now you've got a Walmart on a piece of land that could have been very productive. So, it just helps communities make better land-use decisions and to have reliable geographic data on where resources are or where natural disaster risks are located.

Not surprisingly, multiple stakeholders expressed a desire to learn as much about this trend as possible and make contributions in the renewable energy sector moving forward. GIS can be an invaluable resource for social priorities if used well and efficiently with buy-in from leadership. Gabriel (state government) sums up this perspective "GIS can change the world."

Sub Research Question 4

The fourth sub research question for this study was: *How does the industry structural shift in the geospatial workforce impact geospatial stakeholders?* The trends under the industry structural shift driver include open geospatial science and collaboration, private sector growth/influence, talent, and consumer shift, and enabling diversity.

Private sector growth has enabled cross-sector collaborations, web mapping, mobile mapping, and many other aspects of the geospatial workforce. Despite these benefits, stakeholders in this study did not resonate with the private sector growth trend. Matthew, a professor, said, "I had no idea what it means to shift private sector from physical to digital business models." Free and open data did resonate with stakeholders in all cases and was valued as contributing to a sense of geospatial community. Stakeholders in the data collaboration theme group ranked open geospatial data sources as the most important trend. Stakeholders from the academic case did not value this trend as much as the other cases as they are not traditionally data creators except in research projects. Joseph, an industry manager, explains that "transparency and teamwork on a dataset makes for the best results." The emergence of open geospatial science and open data is accelerating as GIS becomes more common. Diana, a state agency manager, explains the importance of providing open data to her stakeholders:

> Our success relies heavily on data availability, underlying architecture and technologies, and well-designed, thoughtful, sustainable mechanisms to deliver information to different audiences. Access to both standard data and the emerging ways of enriching that data, data interoperability, and emerging technology expectations around delivery of information are all very relevant.

Open geospatial software was a neutral trend to most stakeholders with no stakeholder choosing it to be most or least relevant. Adam, a local government manager, shares "Admittedly, I've not had much reason to explore this area. It seems like most professionals have access to robust paid applications."

Sharing of best practices was universally valued. Anna (state government) shared "I really benefit from GIS user groups and online blogs/forums where folks share how they used GIS to solve problems and answer questions." This is valued across stakeholder groups with 63% of participants holding VAMLIS membership and 95% of participants attending GIS user group meetings. Stakeholders in all cases valued geospatial education but had multiple perspectives on what higher education should include in the curriculum. Many stakeholders felt strongly that geospatial education should start in K-12 education. Gabriel, a state agency manager, stated "I feel that our society is desperately lacking geospatial science/study emphasis at the primary education level….To me, this is the most foundational item on the list, and therefore stands the best chance of making long-term beneficial impacts if properly implemented." Jacob, an industry manager, agrees "The sooner GIS, spatial concepts, and geospatially thinking can be introduced in school, the better." Elizabeth, another state agency manager, stated, "teaching students how to be an advocate for geospatial technologies is important." Reskilling, upskilling, and sector skills training were a characteristic trend for the urban fundamentals and technology early adaption theme groups.

Diversity was not so universally agreed upon as a valued skill and the results were non-conclusive. Simon, an industry manager, shared: "I think there are things that society can do to improve diversity in the workforce; however, merit and hard work should drive the future of the industry." Joel, another industry manager, explains his viewpoint "I'm a firm believer that more diversity in a community of practice speaks volumes about where the community is going and what we can do. Technology advances, but people make a practice."

Sub Research Question 5

The fifth sub research question for this study was: *How do geospatial stakeholders characterize the geospatial legislation environment?* The trends under the Evolution of User requirements driver include digital ethics, cybersecurity and privacy, the pace of digital and technology change, and pressure on government institutions. Stakeholders in all cases value the importance of access to authoritative and accurate data. Knowing what to do with that data is where it becomes powerful. The disparity between technology users and government policy occurs because policymakers do not understand how GIS and technology work and evolve together. Isaac, a local government GIS manager explains how this breakdown of understanding leads to problems "this creates an environment where projects are then given to vendors because it is easier to complete and cheaper than hiring a GIS person, which devalues the GIS professional."

Standards were one of the most characteristic trends for the urban fundamentals theme group. This trend was particularly important to state government stakeholders who were the only group to include standards in their open-ended comments. State agencies not only value the use of standards to ensure data quality, but are sometimes involved in the process of development of them. Cybersecurity, privacy, and digital ethics concerns in GIS are not well defined but they impact GIS in terms of interoperability, accessibility, and shareability. Elizabeth, a state agency GIS manager, expresses her perspective "digital ethics is very important especially if a candidate is going into service in the public sector." This is also true in the private sector according to Joseph "so we have seen a huge push in the last year to clean data and really protect that private information and understand what your client understands as private information because everyone has a different criterion for what that is."

Summary

Chapter four provides the results and findings of the data analysis for this study. This study used interviews and Q Methodology to examine the perceptions of 41 geospatial stakeholders of the drivers and trends in the UN-GGIM Future Trends Report. The four viewpoints that were identified are social education, technology early adoption, data collaboration, and urban fundamentals. The study also evaluated current geospatial courses offerings at Virginia colleges and universities and DOLETA documentation. The researcher confirmed that Q Methodology is an effective method to evaluate geospatial stakeholder perceptions and is a beneficial supporting methodology for qualitative research.

CHAPTER FIVE: CONCLUSION

Overview

The purpose of this exploratory collective case study is to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia. The study began with a review of the background of GIS and the need for education to adapt to the workforce drivers and trends of the intelligent web mapping era. Spatial cognition is the theoretical framework of the study. Previous research has sought to determine how GIS impacts spatial cognition, understand GIS trends that affect the workforce, and improve geospatial education curriculum, but an absence of a study evaluating how higher education can meet the emerging geospatial drivers and trends affecting the workforce in the intelligent web mapping era represented a gap in research. The geospatial profession is constantly evolving and geospatial education needs to be responsive. The study revealed concerns that geospatial education is not adequately addressing the emerging intelligent web mapping era drivers and trends that the geospatial workforce values – indicating that there is an education-workforce divide in the field of GIS. Chapter five reviews the findings of the study, a discussion of implications, delimitations and limitations, and recommendations for future research.

Discussion

This section explains how the findings of the study align with the empirical and theoretical literature reviewed in Chapter Two relating how geospatial stakeholders perceive that geospatial education can meet emerging intelligent web mapping geospatial workforce needs. Themes developed across cases identified the perceptions of stakeholders on emerging drivers and trends in the geospatial workforce. Literature supports the findings that the emerging geospatial drivers and trends are important to the geospatial workforce.

Interpretation of Findings

Summary of Thematic Findings

This exploratory collective case study investigated the perceptions of Virginia geospatial stakeholders about how geospatial education can meet emerging intelligent web mapping geospatial workforce needs. This study used qualitative methodology supported by interviews, Q Methodology and documentation in the form of a collective case study. The decision to use this methodology was suitable to increase the reliability and validity of the study. The study identified four themes across all four case studies of stakeholder perceptions: social education, technology early adoption, data collaboration, and urban fundamentals. The content of these themes reflects answers for each of the research questions in the study.

Interpretations

Finding 1: This study investigated how educators, state government mangers, local government managers, and industry stakeholders perceive the emerging geospatial drivers and trends that are impacting the geospatial workplace. Participants in the study described the trends that they currently use in their work and how they perceive the role of geospatial drivers and trends in the workforce in the future. All four cases revealed concerns that geospatial education is not doing enough to address the emerging drivers and trends of the intelligent web mapping era that the geospatial workforce values revealing an education-workforce divide in the field of GIS. Four distinct viewpoints or themes were revealed which express different perspectives of Virginia stakeholders who participated in this study. The researcher provided a descriptive narrative on each of these themes. The themes that emerged from this study were social education, technology early adoption, data collaboration, and urban fundamentals.

Each of the theme groups focuses on trends that are applicable and important to the perspectives of a collective group of stakeholders. The social education theme perspective focuses on real-world applications in climate change, renewable energy, sustainability, and education as well as the concerns of diversity in the workplace. The technology early adoption theme viewpoint reflects a focus on agile technological forces of change such as 5G, cloud computing, and IoT. The data collaboration theme participants value collaboration and sharing best practices through networking, open geospatial data and data integration, interoperability, and shareability. They greatly value data sources such as LiDAR, bathymetry, and imagery. The urban fundamentals theme is comprised of well-rounded realists with an informed interest in the government's role in GIS. This theme values fundamental practical urban solutions, re-skilling of the workforce to accomplish goals, and using proven GIS methods.

Finding 2: The study investigated how geospatial stakeholders describe emerging technological advancements in the geospatial workforce. Stakeholders in all four cases believe that artificial intelligence/machine learning has the potential of creating a paradigm shift in the geospatial industry. Stakeholders have a desire to learn to develop data models and algorithms to sort through data and query it intelligently. They agree that this should be one of the most important trends we watch in our profession. Cloud-based computing was particularly important to academia who valued having access from anywhere with minimal infrastructure. Academia stakeholders have a strong interest in cloud computing and service-oriented architecture. GIS as a service opens up the power of spatial analysis and geospatial information accessibility. One of the stated benefits of this technological advancement is that software as a service allows for users who are not trained on GIS software to leverage spatial analysis. Platform as a service and infrastructure as a service are described as having the potential to change the way enterprise GIS architecture is implemented.

Three-dimensional modeling and visualization are also technological advancements valued by stakeholders. Stakeholders report that both non-mapping visualizations and visualization of data such as LiDAR were useful for their work. Modeling and visualization are seen as trends in which stakeholders would like to gain more experience and training. One aspect of 3D visualization in which most stakeholders do not see value is virtual and augmented reality. Only one stakeholder said this trend is relevant to his work.

Similarly, most stakeholders in this study agree that seamless integration between indoor and outdoor mapping is not relevant to their work. Some participants relate that they have not heard of the term digital twin. Others value this trend due to the benefits to urban environments of real-time data collected by sensors to be streamed and modeled or visualized by utilizing IoT. Stakeholders in all four cases ranked edge computing and the semantic web trend as not relevant. In the Q-Methodology, 88% of respondents ranked this trend in the position of 0 or lower tying it for the collective least relevant topic to stakeholders. Many describe this as a confusing niche topic that they collectively did not deem very relevant.

Another trend that is not yet developed but has the potential to be disruptive to the geospatial industry is quantum computing. Many stakeholders in the study were unfamiliar with this technology with 78 % ranking it as not relevant. Quantum computing can significantly outperform current computer systems making it possible to utilize large numbers of variables in a single operation (CompTia, 2021). The UN-GGIM Future Trends Report (2020) noted that quantum computing has great future potential for big data processing for GIS analysis so although they do not value it now, it should remain on the radar of Virginia geospatial stakeholders.

Finding 3: The study investigated how geospatial stakeholders perceive the rise of new data sources and analytical methods in the geospatial workforce. New data sources (big data, linked data, social media, crowdsourced data) have emerged in the geospatial workforce. Linked data which refers to geospatially enabled statistics is valued by participants as a method to enable data integration with great future potential for the geospatial industry. Participants describe the value of linked data for recognizing trends in communities such as mapping crime data. Data science including big data and data analytics is viewed as the trend that is most closely aligned to geospatial science by study participants. GIS is perceived as having a transformative impact on big data through location-based analytics. Integrating GIS and data science in education programs is viewed as a priority among the participants. Participants across all cases expressed a desire to get training on data analytics and specifically learn how automated intelligence and machine learning could be used for geospatial data analytics. They advise geospatial education to introduce these concepts as part of Advanced GIS coursework.

There are two data trends from the United Nations Future Trends Report (2020) that are not relevant to the stakeholders in this study. None of the participants perceive social media data through geolocation as being a significant trend. One local government stakeholder, who chose social media data as the least relevant trend, describes it as having “limited value due to the intent of social popularity and visual appeal.” This perception fails to recognize broader use case applications outside of its original purpose. Most participants are also leery of crowdsourced data and lack confidence that the technique could lead to quality or accurate data. Delilah, a state agency GIS manager shared that she would prefer that this not be a trend at all.

Increased availability of existing data sources such as remote sensing data (satellite, imagery, LiDAR, bathymetry) is important to stakeholders across all cases. This is considered one of the highest value trends for the local government case. Participants note that the technology costs are becoming less of an obstacle to acquire LiDAR, imagery, bathymetry, UAV, and satellite data making it easier to adopt. Virginia has statewide LiDAR collected by federal agency partnerships and statewide imagery is collected every four years through VGIN. Even with the acquisition of new topo bathymetric LiDAR in some areas, there are still huge data gaps in shallow water bathymetry in Virginia. Stakeholders in the study report that this data is useful in Virginia for research including sea-level rise efforts (coastal inundation mapping), changes in nearshore environments (beaches, marshes), sediment transport models, and storm surge models. Several participants mention mapping the ocean floor as a trend that should be given more significance but did not rate it highly as a trend because it is not relevant to them personally. UAV data collection was given priority by academia, but not by other cases.

As a result of increased data availability, the integration, interoperability, and shareability of data has grown exponentially over the past few years and is of particular interest to the geospatial professionals in this study. Sharing data with the public for download and the ability to collaboratively manage and edit data online is also important to participants. One participant noted the importance of metadata and making sure data is cited properly. Most participant comments relate to data access, quality, etc. but they also express the importance of education in the discovery, use, application, and interpretation of data.

Finding 4: The study investigated how geospatial stakeholders describe the evolution of user requirements. User requirements for geospatial stakeholders have evolved considerably in the past ten years. Although the impact of digital natives is not perceived to be an important trend to the stakeholders in this study, the younger generations have different demands requiring technology to be mobile, frictionless, convenient, personalized, interactive, social, and ratable. These expectations have been the catalyst for the demand for real-time geospatial data provision. The use cases for real-time data are especially important to Virginia stakeholders.

The local government case cites public safety demands for real-time tracking of resources such as snowplows, busses, and fire trucks. State agency stakeholders value mission-ready data from authoritative sources. Emergency response use cases are perceived as critical by stakeholders in all cases with this being one of the most highly valued geospatial trends. Many emergency management agencies have adopted geospatially based operation models (including disaster planning, mitigation, response, and recovery). However, stakeholders report that investment in geospatial resources in emergency management varies widely across organizations in Virginia. A surprising number of 911 centers rely on vendors for GIS, have older versions of software, or inefficient platforms that are not using GIS to its potential.

Open data is greatly valued by study participants who describe use cases in their current roles. Open data is often mentioned in research as one way that GIS can help to bridge the digital divide. However, practitioners and researchers alike often fail to realize the potential for exclusion of marginalized groups still exists without proper internet access and training on GIS skills. GIS analysis is also seen by several stakeholders in this study as a tool being used to shed some light on the relationship between race, poverty, and location and as a method to provide opportunities for equality.

Use cases for the geospatial role in addressing social priorities are also valued by many participants. One of the social priorities that stakeholders in the study value most is using GIS to support a sustainable world. This is valued very highly by those that mentioned it especially by those who align with the social education theme. Geospatial solutions are being developed to meet UN goals for a sustainable future. Stakeholders feel that GIS should be the primary tool for creating that future, especially when addressing climate change. Stakeholders who valued GIS use in climate change believe that it has the potential to make a global difference that could save lives. The use case in renewable energy is also an important trend to Virginia stakeholders. One notable piece of evidence is that The Virginia Department of Mines and Minerals changed the name of the state agency to Virginia Energy on October 1, 2021.

Finding 5: The study investigated how the industry structural shift in the geospatial workforce impacts geospatial stakeholders. Stakeholders in this study do acknowledge the influence of private sector growth in the geospatial industry. However, several participants noted that they do not understand the concept of the shift from a physical to a digital business model while others do not think it is a primary trend. The trend that participants do value to a very high degree is open geospatial science with stakeholders from the state government, industry, and academia cases mentioning it multiple times in the interviews and open-ended questions. Open geospatial science is described as incredibly useful to stakeholders in this study with benefits including ease of use in web mapping applications for the public and data sharing. The proliferation of open data and web mapping applications has led to the concept of mapping for the masses.

Interestingly, local and state government stakeholders express that they view one of their primary responsibilities as providing efficient ways for citizens to access the data they create. One valid concern for open data is that if the user does not understand how the data was created or the purpose, they may use it incorrectly or inappropriately, making a strong case for good metadata. The one aspect of open geospatial science that stakeholders do not value is open source GIS software. Stakeholders in all four cases (88%) ranked open source GIS software in the position of 0 or lower tying it with edge computing and the semantic web trend as the collective least relevant trend.

A trend that stakeholders in this study do value is the talent and consumer shift. Stakeholders express that geographical literacy is lacking on the elementary school level and that geography understanding and awareness should be addressed early with continued emphasis and technical GIS skills being integrated into the middle and high school education curriculum. This could have a cascading effect on the quality of geospatial education and the preparation of students to succeed in the workforce. Also, stakeholders recommend that Advanced GIS classes cover most of the trends examined in this study by introducing students to potential career paths in the field of GIS.

Upskilling and reskilling the workforce to do higher-level tasks was valuable to stakeholders in the technology early adoption case, who recognize that as technology evolves, the need to learn new skills increases. To implement the new technology, employers need to educate and train staff to ensure they can be successful. Examples shared by several stakeholders include the shift to an enterprise GIS environment, understanding data analytics, and the increased need for scripting and programming skills such as proficiency with Python. Professional development is desired by every stakeholder in the study with learning about artificial intelligence, data analytics, LiDAR, and Python cited frequently. Stakeholders, however, do not feel that employers do an adequate job of training. One stakeholder bemoans that retraining people to use GIS is something that is not usually done in our field. Another stakeholder notes that he had to teach himself to use interoperability tools by watching YouTube videos.

The study revealed diversity of thought and skill among the stakeholders. Stakeholders discussed how they are noticing more and more people in the geospatial sector that come from different disciplines and are crossing over into GIS from other fields. The geospatial community in Virginia can enable diverse professionals to adapt to emerging trends. Stakeholders express value to networking opportunities such as through professional organizations (VAMLIS) and regional user groups that share best practices.

Finding 6: The study investigated how geospatial stakeholders characterize the geospatial legislation environment. Mission-ready authoritative data provided by the government is still a valued priority by Virginia stakeholders. One industry professional pointed out that without standards and data that's been through the QA/QC process to meet those standards, the fanciest software will be useless as the end result will not be useful. They also acknowledge that the concept of digital ownership is complex. This concept is relatively new and without legislation, it is not adequately defined. The government has historically been slow to address GIS governance and policy has not kept pace with the changes in GIS technology. Participants note that digital ownership is somewhat contrary to the traditional GIS community perspective of open and accessible data. Data standards for geospatial data creation and maintenance are essential with cross-sector collaborations for interoperability and have the potential to make the geospatial industry stronger and more collaborative. Therefore, based on the perspective of study participants, it is important to teach students what constitutes authoritative data, data citation, digital ethics, and standards as part of geospatial education.

Implications for Policy or Practice

Addressing how well colleges and universities are meeting emerging intelligent web mapping trends has real-world value for policy and practice. According to the GeoBuiz Report

(2019), the global geospatial market revenue was nearly $300 billion in 2017 and was expected to be $400 billion by 2020. The compound annual growth revenue rate (CAGR) for the geospatial industry over the period of 2013-2017 was 11.5% and was forecasted to be 13.6% for 2017-2020. Remarkably, the economic impact of the geospatial industry from 2013-2017 grew at 20.9%, almost twice the rate of the CAGR for revenue indicating that geospatial technology advancements have a multiplier effect on the economy and on society (GeoBuiz Report, 2019).

With the upward revenue and impact trends in the geospatial industry, it is critical that higher education produces a qualified workforce. Addressing gaps identified will benefit students and employers and attempt to bridge the geospatial education-workforce divide in the field of GIS that was revealed by the findings of this study. The quality of education can improve by addressing curriculum to include trends that are valuable to the geospatial workforce. This will lead to student success in the workforce. This study identified four implications for policy and practice in geospatial education. These implications are emphasis on foundational GIS concepts, agile curriculum and faculty, interdisciplinary approach, and increased collaboration.

Emphasis on Foundational GIS Concepts

A good foundational understanding of spatial methods was recommended by all stakeholders across the four cases, but this concept was central to the urban fundamental theme. It is challenging to cover all the fundamentals in a semester so this study addressed the question of what constitutes a good geospatial foundation. The GTCM defines “cross-cutting geospatial abilities and knowledge" which align with the concept of GIS fundamentals as described by study participants.

The specific basic geospatial skills recommended differed among stakeholders, but the sentiment that foundational concepts were of the utmost importance was universally accepted.

Spatial thinking was a frequently mentioned concept that should be included in GIS education. Theory should be introduced in higher education before software operation. Several tasks were generally agreed upon by stakeholders including data manipulation, data structures, database fundamentals, data interoperability, core concepts of spatial analysis, editing, and cartography. Data sharing, the ability to find data, data accuracy, and data ethics were also mentioned. Findings in the study did not indicate a value in teaching open-source software. In addition to these basic GIS skills, many stakeholders indicated that the workforce also values soft skills such as communication, project management, technical writing, sales, and problem-solving.

Agile curriculum and faculty

The fundamental core geospatial skills are static and remain the same regardless of what technology is implemented. The cutting edge of GIS is diametrically the opposite, and changes from year to year, requiring an agile response. This is one of the most important takeaways for educators of advanced GIS topics according to industry stakeholders in this study.

Educators should be prepared to frequently change the curriculum. As GIS becomes more pervasive in many fields of the workforce, it will not be enough to teach students to be proficient in the latest software. To become a differentiator in a high-tech workforce, students will need advanced skills such as multi-temporal skills including 3D visualization, public cloud in enterprise GIS, and Python in GIS development according to Job who is a GIS architect for higher education. The trends of the intelligent web mapping era in this study are hot in 2022; however, other technologies will be relevant in 5, 10, or 20 years from now. Educators should not teach their class in a way that is date obsolete. It may be necessary to revise or even completely scrap and re-write the curriculum over time.

Educators that teach advanced spatial concepts will need to be talented agile faculty to keep pace with technology trends and adapt their curriculum to keep their graduates relevant to the workforce. Higher education should consider hiring Professors of Practice, which is a designation that denotes both academic scholarship and practical experience in a particular field. This is desirable in the field of GIS to give students a deeper understanding that goes beyond traditional approaches and prepares them for the rapidly changing geospatial workforce. This designation will allow colleges and universities to attract actual experts in the field of GIS, not just scholars with 30 credit hours of GIS coursework or a Ph.D. in the desired discipline such as Geography.

Another important consideration is the term GIS Professional. This term is currently loosely defined as an arbitrary level of experience or holding certification that very few in the industry possess according to Li et al. (2020). The geospatial industry has the potential to evolve and re-evaluate what it means to be a GIS Professional by adopting some of the practices in other professions with specialized expertise. For instance, placing higher emphasis on GISP industry certification may lead to the workforce compensating accordingly. The new Geospatial Educator's Certification Program (GeoEdC) offers promise for credentialing GIS educators in the future demonstrating that geospatial credentialing is progressing and gaining traction. The employers in this study recognize and value industry certification credentials as an effective way for candidates to prove their GIS expertise.

GIS trends in industry and government do not have a conclusive end date, therefore requiring geospatial education to be particularly agile to remain relevant as more industries realize its value and importance. As Silas, a local government GIS manager reflected “I think trends in the overall technology will happen regardless of the direction GIS is moving. A rising tide will lift all ships."

Interdisciplinary Approach

Foundational GIS skills are extremely important, but adding value at the high end of the spectrum is what's going to differentiate people as geospatial professionals and not just professionals who use GIS. Exposure to emerging intelligent web mapping era trends was universally endorsed by all cases. Ideally, this would typically occur on a broad scale in an Introduction to GIS course, but in more detail in Advanced GIS courses. Many stakeholders advised an interdisciplinary approach. Many colleges and universities such as Liberty University only offer one or two introductory courses in GIS as part of a Geography degree program. This popular approach severely limits student GIS access and exposure in other disciplines. Most students who are not Geography or Environmental Science majors at universities that have this approach are unaware of the benefits of GIS. None of the stakeholders in the study endorsed this approach to geospatial education. The GIS workforce demands integration in multiple disciplines.

There are several alternative paths to interdisciplinary GIS that can be effective. Most larger institutions such as Old Dominion University, University of Virginia, and Virginia Tech have dedicated geospatial research centers for GIS staffed with a Director (GIS expert) who can assist faculty and students with spatial analysis. This is a very effective and productive resource that is utilized abundantly according to academia stakeholders at universities that have a GIS Center. These centers provide a location for students to access geospatial and remote sensing software and data. They also provide valuable location-based services across campus for all academic departments and non-academic offices such as sustainability and facilities. Some institutions such as Radford University have a department in Geospatial Science. Geospatial Science departments may increase the exposure of trends as they are likely to focus on the varied interests and strengths of faculty which can increase the diversity of thought. The trend toward decreasing full-time faculty in state universities makes it even more difficult to meet this objective.

The geospatial community is getting more diverse and is being utilized by so many disciplines and industries. As Luke, a GIS professor notes, claiming to be a GIS professional is like saying you are a doctor. What type? What specialty? In the GIS-specific workforce, enterprise GIS, advanced spatial analysis, and application development can form very different and separate career tracks. Based on research findings, distinctions in GIS-centric career paths should be addressed in higher education. The GTCM aligns with this approach noting three overarching GIS umbrellas to define paths of specialization - positioning and data acquisition, analysis and modeling, and application development. URISA also addresses higher level specialization such as Enterprise GIS under the GTCM management competencies. Virginia Tech and George Mason University are good examples of how specialization in GIS can be effective. These universities offer degree programs in Geographic Information Systems with paths for specialization such as sustainability, geospatial intelligence, or environmental GIS. Based on the findings of this study, this model is the ideal way to build a robust interdisciplinary GIS program, however, it requires significant investment and buy-in from leadership and may be out of reach for colleges and universities with limited resources.

Multiple colleges and universities in Virginia such as Longwood, Radford, and Bridgewater offer a Minor in GIS. This allows students to major in another discipline but still gain valuable GIS skills. Different disciplines in higher education need to focus on different trends for the benefit of their majors. For instance, Geology programs might focus on the use of GIS for mapping resources and hazards. Anthropology programs might focus on the spatial distribution of cultural features and archeological sites. Divinity students might focus on the location significance of important events in the Bible. This approach has merit but is limited by the number and type of courses that can be offered for a minor.

Several colleges and universities offer geospatial certificate programs for credit such as Old Dominion University which offers both undergraduate and graduate certificates. University of Richmond offers a non-credit workforce geospatial certificate. These approaches allow for specialization and have significant benefits to working professionals who wish to gain expertise or switch careers. It is less applicable to traditional college students who have a limited number of credits to take and need to choose options that will be approved for financial aid. Study findings reveal that stakeholders in the geospatial workforce universally want professional development in emerging intelligent web mapping era trends. Several participants mentioned pursuing higher education geospatial certificate programs. They expressed the value of having the credential but lamented the lack of alignment of certificate programs to specific workforce needs and the significant commitment (time and money) of attending higher education classes while working full time.

Many of the intelligent web mapping era trends in GIS researched in this study are interdisciplinary in nature and relevant to other fields. One trend, in particular, spatial data science, is noted by stakeholders as becoming more prevalent with concepts that are understood by many different disciplines. So much of GIS analysis can be classified as data analytics making it of particular importance. Multiple institutions in Virginia have developed data science degree programs (Virginia Tech, University of Virginia, Virginia Commonwealth University, George Mason, Radford and William & Mary). Currently in Virginia, only Radford University has addressed integration of data science and geospatial technology by offering a degree program in Geospatial Science with a specialization in GIS, Remote Sensing, and Data Analytics.

Stakeholders reflected on their journey to specialize in different areas of GIS throughout their careers based on their interests and abilities. They recommend that a GIS curriculum needs to include an overview of many of the trends, so that students have at the very least, a passing introduction to them in Introductory GIS courses. For new employees in earlier stages in their careers, knowing about their options is very valuable. When graduates are applying for jobs, this knowledge can play a role in the areas in which they might wind up specializing. The development of a new course that provides a survey of emerging geospatial technologies aligns with interview and Q Methodology findings. The T approach that Matthias recommends, would be an effective model for an exploratory course, exposing students to how GIS is used in a different emerging geospatial technology in weekly lessons and then allow the student to specialize for a semester project. Expanding this concept, this exploratory course could be guided by a textbook highlighting the emerging geospatial trends with supplementary real-world activities that could increase student exposure across disciplines. A classroom friendly textbook of this nature does not currently exist, but is needed if higher education is to prepare students for emerging geospatial intelligent web mapping trends in the workforce.

One college in Virginia has developed a novel approach that could be a new model for GIS as an interdisciplinary approach. Ferrum College offers an introductory GIS class as an option for the Natural Science General Education Requirement. This unique approach offers students the option to choose GIS as part of their core general education requirements allowing all students to gain GIS skills that they can apply in any discipline. The argument could also be made for including GIS as an information literacy, critical thinking, research, or social science general education requirement option. This approach is consistent with the recommendations of stakeholders in this study. It provides the most interdisciplinary exposure for GIS (giving all students the opportunity to gain the benefits of GIS) and it is the least resource intensive method. The premise is that if GIS is a general education requirement option, after exposure students will naturally use GIS more in their academic pursuits, leading professors in all discplines to seek GIS integration in both their research and their respective content areas. The GIS program will grow exponentially and organically leading to specialized GIS degree programs, minors, and certificates.

Increased Collaboration

The purpose of this study was to gain stakeholder perception of emerging trends in the geospatial workforce. The practice of acquiring industry feedback is rare in academia. The prevailing mindset of focusing on theoretical concepts such as teaching people to think is effective in some fields such as philosophy or the language arts but is not appropriate for a technical field. If colleges and universities relax on the ivory tower, they risk becoming irrelevant particularly in areas of rapid technological advancement. Higher education must combine relevant skills with theory to make students marketable in the workforce. Stakeholders recommended that higher education should regularly check the pulse of what is going on in the geospatial industry and develop a feedback mechanism.

One method is to engage advisory boards allowing industry stakeholders to guide academia. Advisory boards provide opportunities for two-way communication providing not only input from employers, but also a way for academia to request funding, internship opportunities, and partnerships with industry. Another method is the process of developing a curriculum (DACUM) activity. This process allows stakeholders to weigh in on the tasks that are needed for the workforce, allowing the researcher to evaluate emerging viewpoints. It is location-specific, making it locally or regionally beneficial. Q methodology is recommended by Jackson (2020) as a feedback instrument for the DACUM process. Virginia currently has a DACUM for GIS Technician which was developed in 2008 (Appendix I). Based on the results of this research, it would be appropriate for the Virginia DACUM to be re-visited to reflect current workforce requirements.

The workplace is where geospatial education will continue in earnest with on-the-job learning experiences where new employees will get exposed to real-world aspects that will be more meaningful than any lecture in a class. The workplace is also where knowledge and skill gaps becomes evident. These gaps differ for each person and scenario, which is likely what led to the universal call for geospatial professional development by study participants on many diverse topics. While, ESRI and MOOC do provide upskilling options for the geospatial workforce, higher education may be missing out on an opportunity to meet this industry professional development demand. Collaborating with industry to offer short professional development focused special topic courses is not currently a typical higher education practice in the GIS field. It is, however, a provocative opportunity. Micro Certificates may be the solution. This approach allows for very customizable GIS certification based on industry collaboration that could have benefits for both higher education and industry.

This study discovered that the perspectives of academia diverged from those of state and local government in multiple instances such as academia's disproportionate value on cloud computing and drone technology. Collaboration with other geospatial stakeholders can lead to research projects, grants, data resources, and opportunities for students such as internships. One collaborative practice that is no longer active is the VA Geospatial Archive Resource and Data Exchange Network (GARDEN) initiative through VGIN through which state government datasets were hosted by Virginia academic institutions as open data for research purposes, redundancy, and off-site storage for VGIN. Virginia Tech, the most active GARDEN site has not been updated since 2017. Other university GARDEN websites that linked to mirrored aerial photography and census datasets no longer exist. This valuable collaboration model is a missed opportunity for collaboration not only for VGIN but also other state agencies such as Virginia Energy that have data sets that academic institutions seek such as climate and renewable energy.

Collaboration with government and industry is critical but collaboration with colleagues may be even more important. The study revealed that there is no consistency across colleges and universities on how geospatial education is provided. There is also no consistency in the curriculum. Each professor relies heavily on their expertise, strengths, and experience leading to vastly different approaches and outcomes. It would be unwise to advocate for uniformity in the curriculum as this can also be considered a strength; however, the results of this study indicate that collaboration and sharing of best practices are needed in geospatial academia.

GIS professors at colleges and universities may run into each other at the VAMLIS conference or regional user group meetings but the purpose of these meetings is not for academic collaboration. Virginia Tech manages the state-wide software license for academia. They also offer training for ArcGIS online annually and have a comprehensive list of academic GIS contacts and professors. It is recommended that GIS academia build on these collaboration efforts to form an academia specific user group that meets quarterly to discuss trends of interest collectively. The findings of this study revealed a significant value of several intelligent web mapping trends such as open data, open geospatial science, automated intelligence, data science, remote sensing, and Python. An emphasis on user requirements in the areas of climate change, renewable energy, and sustainability was also revealed. As part of the academia user group meetings, academia would be wise to consider collective training webinars on these geospatial trends. This could lead to an increase in degree programs, course offerings, and interest in geospatial research across the state.

Theoretical and Empirical Implications

The purpose of this section is to address the theoretical and empirical implications of this study. The recommendations are applicable for institutions of higher education in the Commonwealth of Virginia and can be generalized for other locations. The theoretical framework of spatial cognition and the body of scholarly literature provide implications regarding emerging geospatial drivers and trends in the workforce and how higher education can address them.

Theoretical Literature Implications

The theoretical framework of spatial cognition has significant implications for GIS success in the workforce. Marianne Williamson (1992) shares this quote “Our deepest fear is not that we are inadequate. Our deepest fear is that we are powerful beyond measure.” Study participants expressed how they overcame obstacles and self-doubt as a student or early in their careers to become successful leaders in the GIS community. They characterized GIS as powerful and interdisciplinary. When discussing how geospatial education can best meet workforce needs, these stakeholders often mentioned teaching the foundations of spatial cognition. This study applied Bandura’s (1977) self-efficacy theory and geography concept of spatial thinking to form an integrated theoretical framework of spatial cognition. In literature, the theoretical framework of spatial cognition is important to GIS education. Utilizing digital GIS technologies in the classroom can positively impact the spatial cognition of students (Gersmehl & Gersmehl, 2007; see also Bearman et al., 2015; Collins, 2017; Golledge et al., 2008; Kim & Bednarz, 2013). Kerski (2021) lists 10 specific impacts of students using GIS in the classroom to include spatial thinking, critical thinking, project-based learning, geographic and scientific inquiry, data fluency, community connection, mobile workforces, career pathways, content knowledge, and students as change agents. These benefits align with the study finding that GIS should be considered as a general education core requirement to provide interdisciplinary access. The benefits also align with study findings of the desired skills that employers are seeking in GIS candidates entering the geospatial workforce. This study confirms previous research on spatial cognition by validating that geospatial education should actively teach spatial cognition skills and that these skills are valued in the workforce. It also extends it by finding that stakeholders expect geospatial education to encourage students to consider how GIS can be powerful in their chosen profession and to maximize their talents by specialization as they prepare for a geospatial career.

Empirical Literature Implications

This study explored several aspects of geospatial education including spatial cognition research, ways to prepare students for the geospatial workforce, government influence, and emerging geospatial trends. Research has examined how utilizing GIS in education can lead to an increase in spatial cognition and higher-order spatial thinking skills (Collins, 2017; DeMiquel Gonzales & De Lararo Torres, 2020). Additionally, research has shown web mapping to be an effective method of teaching spatial cognition (Perugini & Bodzin, 2020). This study extends research on spatial cognition by examining the perceptions of geospatial stakeholders on the foundational skills such as spatial thinking that can prepare students for success in the geospatial workforce.

This study examined the literature on the different ways to prepare students for the geospatial workforce. The methods examined were geospatial competency models, professional industry certification, and geospatial education models. Geospatial competencies are used to develop a curriculum for geospatial education. Published research examines the creation of the Geospatial Body of Knowledge (BoK) and the development of the Geospatial Technology Competency Model (GTCM) through the Department of Labor (DOL) (DiaBiase et al., 2007, 2010; Johnson & Sullivan, 2010). Although multiple studies examine geospatial education through the lens of the GTCM and recommend updates to the GTCM (Tsou & Yarrow, 2010; Fagin et al., 2020), only one study utilized Q Methodology to examine geospatial stakeholder perceptions of the DOLETA GTCM competencies (Jackson, 2020). This study extends previous research by using Q Methodology to examine geospatial stakeholder perceptions of which emerging geospatial workforce trends are important to stakeholders to determine potential updates to DOLETA for competencies not included in the GTCM or O*NET career paths that are emerging. The DOLETA GTCM is considered an authoritative source on the geospatial workforce.

The GISP geospatial industry certification is the most recognized industry credential to demonstrate geospatial competence. Most stakeholders across the four cases value industry certification to indicate they are hiring a qualified candidate. The GSICI which is the largest geospatial certification institute estimates that approximately 2% of the geospatial workforce holds this the GISP industry certification. Although there is an experience requirement of four years to obtain certification, academia could increase the value of this credential by preparing students to take the GISCI Core Technical Exam while in school and encouraging students to start their portfolios. The exam is based on the competencies listed in the DOLETA GTCM.

Although the findings of this study validated the specialization approach of the DOLETA GTCM, emerging trends that are not covered in the DOLETA GTCM will not be covered on the GISP exam leading to potential future knowledge gaps for GIS professionals. Additionally, this study is the first research study to include the new Geospatial Educator's Certification Program (GeoEdC), as a new method for credentialing Geospatial Educators extending previous research on GIS certification. This credential has great potential to align the curriculum and knowledge required to be an effective geospatial educator in the intelligent web mapping era. The impact on the geospatial community or geospatial education is not yet realized.

The geospatial education models that are researched in this study are the K-12 pipeline, institutions of higher education, and industry training. The Geospatial Semester through James Madison University in Virginia provides a pipeline by offering dual-credit GIS classes through the Virginia public school system (Kolvoord et al., 2018). Research has shown that introducing GIS technology and concepts at the K-12 level has many benefits (Baker et al., 2003; Kerski, 2003; Kolvoord, 2020). Research revealed that higher learning institutions have both challenges and opportunities in preparing students for a career in GIS. An examination of the current status of GIS in the state of Virginia revealed a lack of degree programs in GIS and multiple instances of GIS being taught as a silo under a single degree program, particularly at private colleges and universities. Research recommends interdisciplinary approaches to GIS education in higher education (Allen, 2005; Kemp, 2003; Wright et al., 1997). This research extends current research to show the status of GIS in Virginia and stakeholder perceptions of how geospatial education can improve.

Literature on the government's influence on geospatial education was also examined in this study. The government has influenced the geospatial community on global, national, and state levels. The United Nations released the UN-GGIM Future Trends Report in 2020. This report was the result of qualitative research conducted by the United Nations to compile the perceptions of global geospatial experts regarding emerging geospatial trends, making it the most current, comprehensive, and authoritative source of information on emerging geospatial trends. No studies have used this source to examine geospatial trends. This study adds to academic research by examining the Virginia stakeholder perceptions of the emerging geospatial trends in the UN GGIM to determine if their viewpoints align with the UN global experts.

The GIS field is growing and the need for qualified employees is increasing the demand for higher education to effectively prepare students for the workforce. There is a lack of recent literature that dives into what skill sets are necessary for geospatial employment in the intelligent web mapping era. This study extends the empirical literature about emerging geospatial trends in the intelligent web mapping era. Numerous studies have examined individual emerging geospatial trends or evaluated geospatial curricula. Pourabbas (2014) examined the methodological aspects of many emerging geospatial trends. Two studies have researched emerging geospatial trends in the context of the intelligent web mapping era (Veenendaal et al., 2017, Matney, 2019). There are no studies that have examined how higher education can address the emerging geospatial trends of the intelligent web mapping era which was the aim of this study. This study extends empirical literature by examining this gap in research.

Delimitations and Limitations

Purposeful delimitations were chosen as boundaries in the study by the researcher such as participant selection and setting. Additionally, there were unintentional limitations to the study that were revealed through the research process and were not necessarily expected by the researcher.

Delimitations

Delimitations for the study included the selection of the research design, participants, and setting. The research design was qualitative research in the form of a collective case study. The cases for the study were state government, local government, industry, and academia. The study's setting was the Commonwealth of Virginia. This setting was chosen because of the strong collaborative environment among stakeholders. The participants were chosen with criterion sampling which relies on the participant's qualifications (geospatial leadership role for at least one year) to participate in the study (Creswell & Poth, 2018; Yin, 2018). The sample size of the study was 41 participants.

Limitations

Because of the COVID-19, there were limitations with the interview format which was conducted on the Zoom web conferencing platform. All participants were experienced with Zoom, however, there were some technical challenges, and some participants elected to keep their cameras off making the interview less personal. This prevented the researcher from seeing non-verbal cues.

The study was limited by the interest level of participants. The study was limited by the degree to which the study participants are an accurate representation of the larger geospatial community. In addition, the study was limited to only the perceptions of geospatial stakeholders in a leadership role for at least one year. Geospatial stakeholders in non-leadership roles were not included in this study and may have a different perspective. Community college and K-12 geospatial stakeholders were excluded from this study. The participants in this study were limited to those on the VGIN stakeholder database which had very few minority stakeholders who are in a leadership role and fewer women than men who met the study criteria.

An additional limitation occurred with the format of Q Methodology. Q Methodology was used as a supportive method to evaluate geospatial employer viewpoints on emerging drivers and trends. This study confirms the applicability and practicality of the method as a supportive methodology to qualitative research. However, Q methodology is limited by the accuracy of the participants in the sorting process in the Q-sort based on how carefully they considered their choices to accurately represent their viewpoints. Only the drivers and trends that were listed in the UN-GGIM Future Trends Report were included in the study. The Q-Methodology analysis was limited to the items that were part of the Q-sample. There are many trends such as geospatial intelligence and datum updates that were not included in the study.

Recommendations for Future Research

Previous studies have looked at the benefits of teaching GIS, geospatial curriculum, geospatial competencies, and individual emerging geospatial trends. Two studies reviewed emerging geospatial trends in the context of the intelligent web mapping era. However, no previous studies look directly at how geospatial education can address the emerging geospatial drivers and trends of the workforce in the intelligent web mapping era. This study provided stakeholders an opportunity to share their perceptions through individual interviews and Q Methodology. Additional insights were provided by reviewing DOLETA documentation and current geospatial offerings and programs of colleges and universities in Virginia. Multiple directions for future research are recommended.

Considering the delimitations and limitations and the findings from this study, it is recommended that this study be repeated. Not surprisingly given the GIS focus of the study, the researcher received feedback from research participants that future research should be expanded based on location. Aaron, a local government manager, stated “This is fantastic research and should be crowd-sourced and then compared against geographic locations.” Levi, a professor, agreed “I am very interested to see these results. There is also probably variance in relevance based on geographic region.” This research could be repeated in other states or on a national level to examine if the results in Virginia can be replicated. If that were to occur, including other groups of stakeholders that were not part of this study such as community college faculty or GIS stakeholders that are not in leadership positions is recommended in order to discover if they value the same trends or have different viewpoints from the stakeholders in this study.

There are also additional trends that stakeholders mentioned that were omitted in this study that should be part of future research. The researcher acknowledges that geospatial intelligence is a trend that was not studied as part of this research and should be included in future studies to understand stakeholder perceptions. There is a significant military presence in Virginia and research of job openings revealed career opportunities in the emerging trend of geospatial intelligence. A second trend omission in the study revealed by participants is datum updates. Because of COVID-19 impacts, the simultaneous release of the new datums has been postponed, but they will have a huge impact on GIS users. In addition to the new terrestrial datums (gravimetric geoid model rather than ellipsoid based) new tidal datums will also be released. The reference framework GIS professionals use will be changing so the perceptions of this trend need to be captured in future research.

An unexpected finding is that the trend of increased diversity in the workplace produced conflicting results with 12 % of participants placing it in the (-4) or (-5) position and 12% placing it in the (+4) or (+5) position on the Q Methodology pyramid. It was also reported as the most difficult trend to place. These findings are inconclusive on the perception of this trend and are worth investigating. The findings of the disproportionate number of male GIS professionals compared to females in Virginia that hold the GISP industry certification and the finding that GIS education is lacking at HBCUs in Virginia support the argument that diversity is still a concern for the geospatial industry in Virginia. These findings indicate a gap in research that should be explored.

Previous research examined the perceptions of stakeholders on DOLETA GTCM competencies and O*NET job outlooks (Li, 2021). Given the disparity between current job openings on Indeed.com and occupation titles listed on O*NET, more research should be conducted to investigate how DOLETA O*NET should be updated. For example, GIS-specific job titles such as GIS Analyst and GIS Specialist are not currently listed on O*NET but are some of the most common job opportunities for candidates. Seventeen occupation-specific analyst job titles are listed such as News Analyst or Financial Analyst. Forty-one occupation-specific specialist job titles are listed. The GISP certification exam is based on the DOLETA GTCM and O*NET. Therefore, future research on DOLETA could have implications that impact which skills are tested on the certification exam. Future research should evaluate the effectiveness of the new Geospatial Educator's Certification Program (GeoEdC), as a new method for credentialing Geospatial Educators. There is no data available on the GeoEdC at this time.

The researcher recommends using Q methodology to support qualitative research and for future studies that seek to understand stakeholder perceptions. This would also be an effective method to use for research on updates to the Virginia DACUM. For this study, some stakeholders reported difficulty making decisions on how to place trends that they were unfamiliar with on the Q-sort pyramid. I would recommend providing additional explanations and definitions of trends to solve this issue. Otherwise, this Q Methodology is practical and effective for any research that seeks to study the viewpoints of stakeholders.

Conclusions

The purpose of this exploratory collective case study was to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia. Bandura’s (1977) self-efficacy theory and geography concept of spatial thinking form an integrated theoretical framework of spatial cognition for this study. This research study examined the perceptions of GIS stakeholders of geospatial education through four cases – academia, state agency government, local government, and industry. Data collection included in-depth interviews of twelve geospatial stakeholders, supporting Q methodology to determine the viewpoints of 41 geospatial stakeholders, and documentation. Data analysis strategies included cross-case synthesis, direct interpretation, generalizations, factor analysis, and a correlation matrix to show similarities in participants' preferences. Theoretical research enriches the existing literature by describing the value that geospatial stakeholders place on spatial cognition. Empirical research extends the existing literature by revealing four collective viewpoints or themes of geospatial stakeholders regarding the drivers and trends of the intelligent web mapping era– urban fundamentals, technology early adoption, social education, and data collaboration. The research also adds to the existing body of literature by describing how these themes can inform geospatial education decisions on GIS curriculum.

This study has policy and practical implications. First, the findings of this study advance knowledge about the geospatial drivers and trends in the intelligent web mapping era, and more specifically, patterns related to specific cases of academia, state government, local government, and industry. The derived characteristics of these cases depict a holistic picture of the current state of GIS in the Commonwealth of Virginia. Second, this adds to the body of literature by providing four implications for policy and practice in geospatial education on how to bridge the education-workforce divide. These implications of teaching fundamentals, agile faculty and curriculum, emphasis on interdisciplinary approaches, and increased collaboration provide valuable information for GIS educators for improving GIS programs and curricula of higher education institutions. Furthermore, the derived information about geospatial drivers and trends is also useful to students who are interested in GIS as a profession. Lastly, this study can also shed light on opportunities for using Q methodology as a type of data collection and analysis that when used as a qualitative method utilizes sorting by the participant to determine their preferences.

This study has some delimitations such as selection of the research design, participants, and setting. Also, it has limitations including the interest of participants and the format of Q Methodology. Future research could be conducted to further examine the potential reasons for the results found in this study and to determine the extent to which the patterns identified in this study are similar or different in other states or geographic regions. Similar research could be done to investigate the perceptions of participants who were not included in this study including community college faculty and GIS participants who are not in a leadership position. Second, the research could also be conducted to investigate trends such as new datums and geospatial intelligence that were not part of this study to provide valuable insight into the workforce needs of these trends. Another opportunity for future research would be to examine the representation of diversity concerning the geospatial workforce in Virginia. Additionally, future work could also explore if changes are needed in geospatial occupation listings on the DOLETA O*NET or competencies of the GTCM based on emerging drivers and trends in the geospatial workforce. These future research initiatives could help GIS researchers and practitioners develop a better understanding of the geospatial drivers and trends of the intelligent web mapping era and how geospatial education can prepare students for the needs of the geospatial workforce.

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Appendix A: Institutional Board Approval

LIBERTY UNIVERSITY
INSTITUTIONAL REVIEW BOARD

August 31, 2021

Wendy Stout
Carol Gillespie

Re: IRB Exemption - IRB-FY21-22-54 A CASE STUDY OF STAKEHOLDER PERCEPTIONS ON HOW GEOSPATIAL EDUCATION CAN MEET THE EMERGING GEOSPATIAL WORKFORCE NEEDS OF THE INTELLIGENT WEB MAPPING ERA

Dear Wendy Stout, Carol Gillespie,

The Liberty University Institutional Review Board (IRB) has reviewed your application in accordance with the Office for Human Research Protections (OHRP) and Food and Drug Administration (FDA) regulations and finds your study to be exempt from further IRB review. This means you may begin your research with the data safeguarding methods mentioned in your approved application, and no further IRB oversight is required.

Your study falls under the following exemption category, which identifies specific situations in which human participants research is exempt from the policy set forth in 45 CFR 46:104(d):

Category 2.(iii). Research that only includes interactions involving educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior (including visual or auditory recording) if at least one of the following criteria is met:

The information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by §46.111(a)(7).

Your stamped consent form(s) and final versions of your study documents can be found under the Attachments tab within the Submission Details section of your study on Cayuse IRB. Your stamped consent form(s) should be copied and used to gain the consent of your research participants. If you plan to provide your consent information electronically, the contents of the attached consent document(s) should be made available without alteration.

Please note that this exemption only applies to your current research application, and any modifications to your protocol must be reported to the Liberty University IRB for verification of continued exemption status. You may report these changes by completing a modification submission through your Cayuse IRB account.

If you have any questions about this exemption or need assistance in determining whether possible modifications to your protocol would change your exemption status, please email us at irb@liberty.edu.

Sincerely,
G. Michele Baker, MA, CIP
Administrative Chair of Institutional Research
Research Ethics Office

Appendix B: Participant Recruitment Email

[Date]

[Recipient]
[Title]
[Company]
[Address 1]
[Address 2]
[Address 3]

Dear [Recipient]:

As a student the School of Education at Liberty University, I am conducting research as part of the requirements for a doctorate in Instructional Design and Technology. The purpose of my research is to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia, and I am writing to invite eligible participants to join my study.

Participants must be employed as geospatial managers/supervisors and have been in their role for at least one year OR employed at a college or university as geospatial educators/administrators for at least one year. Participants, if willing, will be asked to either complete a one-hour recorded interview or complete an online Q methodology sorting activity. Participants who complete the interview may be asked to review the transcripts of their responses for accuracy. It should take approximately one hour to complete either the interview or the online sorting activity. Names and other identifying information will be requested as part of this study, but the information will remain confidential.

To participate, please click on the below link, and complete the screening survey. If you are found to be eligible, I will contact you to set up an interview or send you the sorting activity. You may contact me for more information.

A consent document is attached to this email. The consent document contains additional information about my research. If you choose to participate, you will need to sign the consent document and return it to me at the time of the interview or online sorting activity.

[screening survey link]

Sincerely,

Wendy Stout
Liberty University

Appendix C: Prequalification Survey

Socio-Demographic Questions

1. How many years have you worked in a geospatial profession?
2. How many years have you been a GIS manager/professor?
3. Are you a Certified Geographic Information Systems Professional (GISP)?
4. If so, in what year did you receive your GISP?
5. How did you receive your GISP?

a. Portfolio
b. Knowledge Exam

6. What is your highest level of education?

a. Some college
b. Associates
c. Bachelors
d. Masters
e. Doctorate

7. At which level(s) did you receive geospatial instruction?

a. Workshops
b. Some college
c. Associates
d. Bachelors
e. Masters
f. Doctorate

8. In what sector do you currently work?

a. Local Government
b. State Government
c. Industry
c. Education

9. In what area of the industry do you currently work?

a. Positioning and Data Acquisition
b. Analysis and Modeling
c. Software and Application Development

10. In what area of the industry have you spent the majority of your career?

a. Positioning and Data Acquisition
b. Analysis and Modeling
c. Software and Application Development

11. What is the size of your current organization?

a. 1-5 employees
b. 6-20 employees
c. 21-50 employees
d. 51-100 employees
e. 100+ employees

12. Are you a supervisor?

a. Yes
b. No

13. How many employees do you supervise?
a. 0 employees
b. 1-5 employees
c. 6-20 employees
d. 21-50 employees
e. 51-100 employees
f. 100+ employees
14. Are you a hiring manager?
a. Yes
b. No
15. Do you participate in hiring committees?
a. Yes
b. No
16. What is your job title?

Appendix D: Geospatial Stakeholder Informed Consent Form

CONSENT FORM

A Case Study of Stakeholder Perceptions on How Geospatial Education Can Meet the Emerging Geospatial Workforce Needs of the Intelligent Web Mapping Era

Wendy Stout
Liberty University
School of Education

You are invited to be in a research study on Geospatial Information Systems. The purpose of this exploratory case study is to discover how geospatial education can meet the needs of the emerging intelligent web mapping era that the geospatial workforce needs in the Commonwealth of Virginia. To participate, you must be employed as a geospatial manager/supervisor and have been in that role for at least one year OR have been employed at a college or university as a geospatial educator/administrator for at least one year. Please read this form and ask any questions you may have before agreeing to be in the study.

Wendy Stout a doctoral candidate in the School of Education at Liberty University, is conducting this study.

Background Information: The purpose of this exploratory case study is to discover how geospatial education can meet emerging intelligent web mapping era geospatial workforce needs in the Commonwealth of Virginia.

Procedures: If you agree to be in this study, I would ask you to do one or more of the following things:

1. Take part in an in-depth interview. The in-depth interview will last approximately one hour and will be video-taped, audio-taped and transcribed. Participants in the interview will be asked to review the transcription for accuracy after the interview. The interview will take approximately one hour.

OR

Participate in a Q-sort activity. A Q-sort is used to examine perspectives by having participants sort a series of statements, typically on a scale from those with which they least agree to those with which they most agree. The activity forces respondents to make decisions between the competing statements during the ranking process. Q-sort participants will be asked to do the following:
a. Respondents will rank (sort) trends and drivers from the UN Future Trends Report in a Q-Sort activity.
b. Respondents will have the option to provide any additional comments to clarify their selections. Respondents will be asked some clarifying questions at the end of the survey.

The total amount of time that you will be participating in this study to do the Q-sort is approximately 60 minutes. Participants may complete this activity over the course of two weeks.

Risks: There are minimal risks associated with participation in this research, which means they are equal to the risks you would encounter in everyday life.

Benefits: Participants should not expect to receive a direct benefit from taking part in this study. The potential benefits to society are a greater understanding within the geospatial community of the most valued emerging geospatial drivers and trends.

Compensation: Participants will not be compensated for participating in this study.

Confidentiality: The records of this study will be kept private and confidential. In any sort of report I might publish, I will not include any information that will make it possible to identify a subject. Research records will be stored securely, and only the researcher will have access to the records. I may share the data I collect from you for use in future research studies or with other researchers; if I share the data that I collect about you, I will remove any information that could identify you, if applicable, before I share the data.

- Participant responses will be kept confidential through the use of pseudonyms. I will conduct the interviews in a location where others will not easily overhear the conversation.
- Data will be stored on a password locked computer and may be used in future presentations. After three years, all electronic records will be deleted and any hard copy data will be shredded.
- Interviews will be recorded and transcribed. Recordings will be stored on a password locked computer for three years and then erased. Only the researcher will have access to these recordings.

Voluntary Nature of the Study: Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with Liberty University. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

How to Withdraw from the Study: If you choose to withdraw from the study, please contact the researcher at the email address/phone number included in the next paragraph. Should you choose to withdraw, data collected from you will be destroyed immediately and will not be included in this study.

Contacts and Questions: The researcher conducting this study is Wendy Stout. You may ask any questions you have now. If you have questions later, **you are encouraged** to contact her. You may also contact the researcher's faculty chair.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researcher, **you are encouraged** to contact the Institutional Review Board, 1971 University Blvd., Green Hall Ste. 2845, Lynchburg, VA 24515 or email at irb@liberty.edu.

Disclaimer: The Institutional Review Board (IRB) is tasked with ensuring that human subjects research will be conducted in an ethical manner as defined and required by federal regulations. The topics covered and viewpoints expressed or alluded to by student and faculty researchers are those of the researchers and do not necessarily reflect the official policies or positions of Liberty University.

Please notify the researcher if you would like a copy of this information for your records.

Statement of Consent: I have read and understood the above information. I have asked questions and have received answers. I consent to participate in the study.

☐ The researcher has my permission to audio-record and video-record me as part of my participation in this study.

____

Signature of Participant Date

____

Signature of Investigator Date

Appendix E: Geospatial Trends and Drivers in the Q-Sample

Drivers

1. Technological advancements
2. Rise of new data sources & analytical methods
3. Industry structural shift
4. Evolution of user requirements
5. Legislative environment

Trends

Statements

1. Ubiquitous connectivity (through deployment of 5G technology)
2. Digital data infrastructure and the Internet of Things (connected sensors in physical infrastructure that collect vast quantities of data accessible online)
3. Interconnecting transport through intelligent mobility (ex. Connected and Automated Vehicles)
4. Visualizations and Immersive 3D environment technology (Virtual Reality and Augmented Reality)
5. Digital Twins for modeling, simulation, and prediction. (In comparison to static 3D models, digital twins are directly linked to multiple data sources and receive updates continuously)
6. Developing Data Standards for data creation and maintenance (addressing data interoperability, compatibility, format, quality assurance)
7. Realizing the Value of Data through Big Data and Data Analytics (descriptive and predictive analytics)
8. The potential of Artificial Intelligence/Machine Learning Algorithms in Geospatial Production (particularly image analysis and information extraction)
9. Developments in Computing Technologies such as Quantum Computing (enables intensive processing)
10. Data creation from social media platforms using smart phones (ex. geo-tagged photos)
11. Data integration - merged geospatial data for contextualized location enabled insights to reveal patterns and predict behavior
12. Mission Ready Data (Accessibility and Discoverability of Data - via portals, APIs and linked identifiers to enable effective data use)
13. Linked Data (geospatially enabled statistics for social, economic and environmental issues)
14. Edge Computing and the Semantic Web (interconnecting the physical and information technology worlds by simultaneously generating and harvesting spatial data in a format both humans and computers can understand)
15. Cloud Computing and Service Oriented Architecture (Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Software as a Service (SaaS))

16. High resolution Earth Observations/Satellite Technology (small satellites, nano satellites, CubeSAT, Synthetic Aperture Radar (inSAR))
17. Open Geospatial Data Sources/Open Geospatial Data Portals - free and open data sources to provide for analysis with minimal additional user effort and interoperability
18. Unmanned Aerial Vehicles (UAVs/drones) as a viable alternative to conventional mapping for small area surveys
19. Viable and Sustainable Integrated Data Driven Smart City Solutions becoming wide-spread in urban areas.
20. Terrain mapping using mobile laser scanning (MLS) systems mounted to vehicles to measure road and urban environments
21. Mapping the Ocean: Seabed 2030 project to create high resolution bathymetric map of the ocean floor. Also, the increase in availability of bathymetry of coastal and inland waterways and mapping Sea level rise.
22. Growing Geospatial Awareness within national governments (Most nations have developed National Geospatial Master Plans to foster economic growth and combat societal challenges such as climate change, urbanization and resource management)
23. Geospatial Technology Role in Renewable Energy - Solar, Wind, Biomass, Hydropower, Geothermal
24. Licensing, Pricing and Data "ownership" (Digital Rights management) includes Open Data Licensing Harmonization.
25. Digital ethics/ Data Privacy/Cybersecurity addressed by national and international initiatives. Ethical and responsible use of geospatial applications.
26. Disparities between technological advances and government legal and policy frameworks (Addressing policy/legislation shortcomings concerning digital/ technology changes)
27. Geospatial Career Paths have diversified to include many new expert groups such as data science and analytics, computer science, data visualization etc. in addition to GIS analysts, geographers, surveyors, photogrammetrists, and remote sensing and earth observation scientists.
28. Inclusion of geospatial concepts at primary and secondary levels not just higher education.
29. Reskilling and Upskilling of the Geospatial Workforce for higher value tasks (includes skills transfer and knowledge capture)
30. Increased Diversity in the Geospatial Workforce - mix of ages and experience, cultural background, gender, race, and neuro-diverse skillsets.
31. Sector Skills Training - addressing the short term needs of a geo-information sector with occupational skills needed for the workforce through professional development/training.
32. Open Geospatial Science (Sharing of resources among the geospatial community) - transparency and evidence-based reproducible workflows in research, sharing lessons learned, innovative collaboration and publications to allow sharing resources.

33. Development of Geospatial Networking Groups and Geospatial Communities with common interests to share best practices.
34. Making mapping available to the masses - web and mobile mapping changing the volume and type of data consumers and their demands.
35. Shift of Private Sector from a physical to a digital business model blurring the lines between the traditional notion of producers and consumers.
36. Open Source Geospatial Software - software that you can freely access and modify the source code for (as opposed to licensed software which is not free)
37. Increased demand for 3D modeling/visualizations (ex. landforms for mining/landslides or urban environment for infrastructure and construction projects)
38. Citizen Science Participation: Crowdsourcing and Volunteered Geographic Information Systems (New data collection methods)
39. Geospatial role in addressing social priorities - bridging the digital divide, citizen empowerment, marginalized groups, socio-economic disparities, population migration
40. Seamless experience between outdoor/indoor mapping is expected by users.
41. Digital natives have a different expectation of user experience - it should be mobile, frictionless and convenient. Values of personalization, ability to interact with data, digital networking, and recognition (ie. likes).
42. Change in Role of Governments from Spatial Data Infrastructure (authoritative data provider) to Spatial Knowledge Infrastructure (network of data, analytics, expertise and policies)
43. Increased availability and accessibility of high resolution point cloud Lidar data.
44. Emergency management adoption of geospatial based operation models including disaster response (planning, mitigation, response, recovery), police, fire, rescue and 911 calls
45. Geospatial role in developing a sustainable future (2030 Agenda for Sustainable Development) - climate change initiatives, environmental concerns, e-economies, demand for natural resources, resource security, pollution, water stress, deforestation, biodiversity loss

Appendix F: Q Methodology Open Ended Questions

Post Q-sort Qualitative Open-Ended Questions

1. Select a statement that you placed in the 5 column and share the reason for your decision.

2. Select a statement that you placed in the -5 column and share the reason for your decision.

3. Which statement did you have the most difficulty placing and why?

4. What factors helped to determine your sorting decisions?

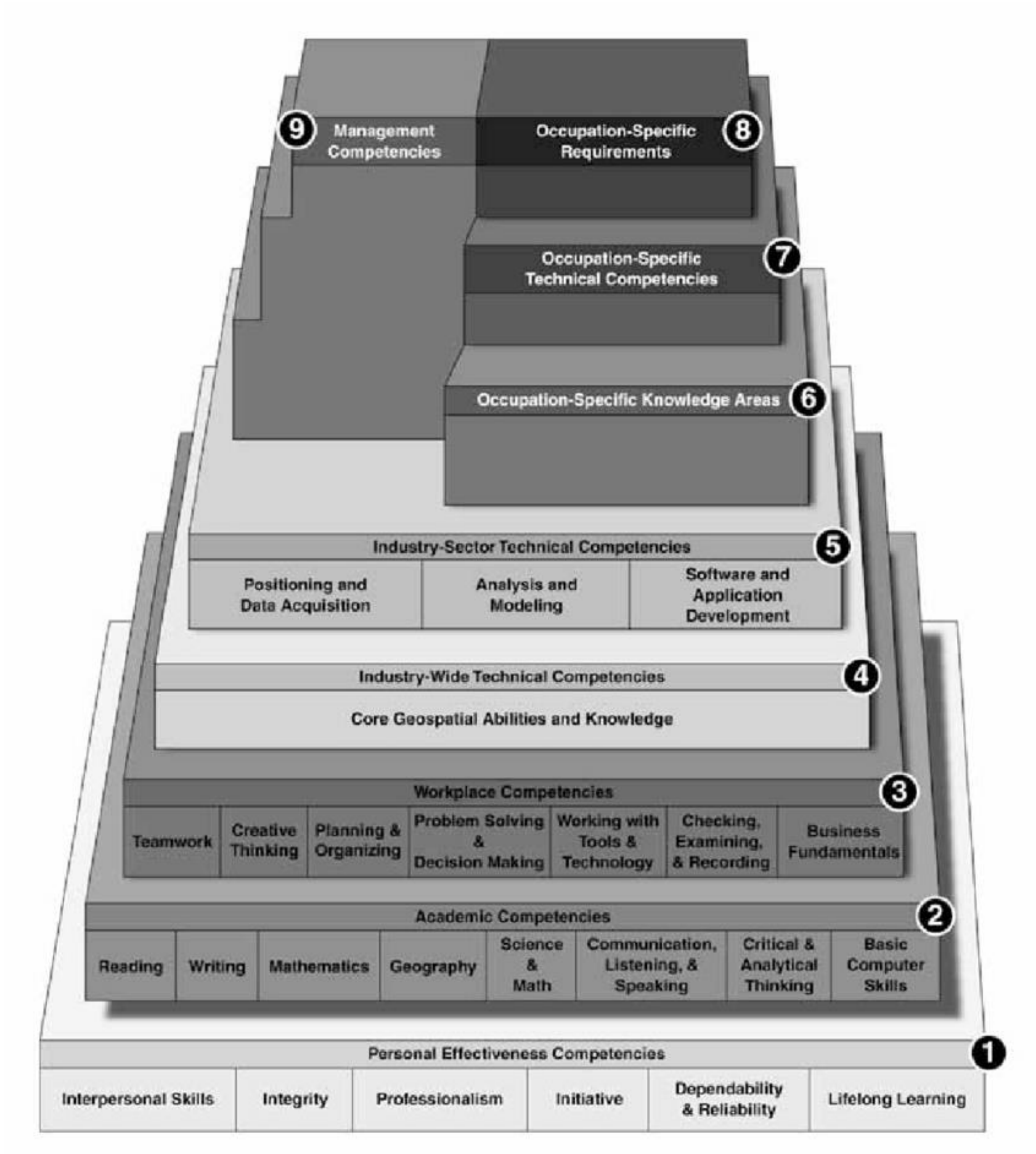
5. Which trends in the Q-sort are relevant to your current work? Please explain.

6. If you could personally receive professional development with no time or cost constraints, which trend(s) included in the Q-sort would you choose and why?

7. Which trend(s) should higher education include in a curriculum for Advanced GIS and why?

8. Please share any additional thoughts not addressed by the questions above (these answers are used as data in determining how we characterize the cumulative perspective held within the geospatial industry).

Appendix G: DOLETA Geospatial Technology Competency Model



Appendix H: Geospatial Offerings at Virginia Colleges and Universities

CHART LEGEND Blue dot- Geospatial Offering ● at College or University	GIS Research Center	GIS PhD Degree	GIS Masters Degree	GIS Bachelors Degree	GIS Graduate Certificate	GIS Undergraduate Certificate	GIS Minor	GIS Courses
PUBLIC FOUR-YEAR INSTITUTIONS								
CHRISTOPHER NEWPORT UNIVERSITY, NEWPORT NEWS								●
COLLEGE OF WILLIAM AND MARY, WILLIAMSBURG	●				●			●
GEORGE MASON UNIVERSITY, FAIRFAX		●	●	●	●	●	●	●
JAMES MADISON UNIVERSITY, HARRISONBURG	●			●				●
LONGWOOD UNIVERSITY, FARMVILLE							●	●
NORFOLK STATE UNIVERSITY, NORFOLK								
OLD DOMINION UNIVERSITY, NORFOLK	●				●	●		●
RADFORD UNIVERSITY, RADFORD	●			●		●	●	●
UNIVERSITY OF MARY WASHINGTON, FREDERICKSBURG			●			●		●
UNIVERSITY OF VIRGINIA, CHARLOTTESVILLE	●							●
UVA'S COLLEGE AT WISE, WISE								●
VIRGINIA COMMONWEALTH UNIVERSITY, RICHMOND	●				●			●
VIRGINIA MILITARY INSTITUTE, LEXINGTON								●
VIRGINIA STATE UNIVERSITY, PETERSBURG								●
VIRGINIA TECH, BLACKSBURG	●	●	●	●	●		●	●
PRIVATE NON-PROFIT FOUR-YEAR INSTITUTIONS								
AVERETT UNIVERSITY, DANVILLE								
BLUEFIELD COLLEGE, BLUEFIELD								
BRIDGEWATER COLLEGE, BRIDGEWATER							●	●
CHRISTENDOM COLLEGE, FRONT ROYAL								
EASTERN MENNONITE UNIVERSITY, HARRISONBURG								●
EMORY & HENRY COLLEGE, EMORY								●
FERRUM COLLEGE, FERRUM								●
GEORGE WASHINGTON UNIVERSITY (VA CAMPUS), ASHBURN								
HAMPDEN-SYDNEY COLLEGE, HAMPDEN-SYDNEY								
HAMPTON UNIVERSITY, HAMPTON								
HOLLINS UNIVERSITY, ROANOKE								●
JEFFERSON COLLEGE OF HEALTH SCIENCES, ROANOKE								
LIBERTY UNIVERSITY, LYNCHBURG								●
UNIVERSITY OF LYNCHBURG, LYNCHBURG								●
MARY BALDWIN COLLEGE, STAUNTON								
MARYMOUNT UNIVERSITY, ARLINGTON								
RANDOLPH COLLEGE, LYNCHBURG								
RANDOLPH MACON COLLEGE, ASHLAND								●
REGENT UNIVERSITY, VIRGINIA BEACH								
ROANOKE COLLEGE, SALEM								●
SHENANDOAH UNIVERSITY, WINCHESTER								●
SOUTHERN VIRGINIA UNIVERSITY, BUENA VISTA								
SWEET BRIAR COLLEGE, SWEET BRIAR								
UNIVERSITY OF RICHMOND, RICHMOND	●							●
VIRGINIA UNION UNIVERSITY, RICHMOND								
VIRGINIA WESLEYAN COLLEGE, NORFOLK								●
WASHINGTON AND LEE UNIVERSITY, LEXINGTON								

Appendix I: Virginia DACUM for GIS Technician

DACUM Research Chart for: GIS Technician

	Duties	Tasks											
A	Create / Acquire GIS Data (3)	A-1 Define data requirements	A-2 Research available data	A-3 Purchase new data	A-4 Develop databases (e.g. define geometry, attributes)	A-5 Define feature relationships/ behaviors (e.g. relate tables, relationship classes)		A-6 Define feature behaviors (e.g. sub-types & domains)		A-7 COGO legal descriptions	A-8 Perform tablet digitization	A-9 Perform "heads-up" (on-screen) digitization	A-10 Geocode data
A	Create / Acquire GIS Data (3) - continued	A-11 Determine data compatibility (e.g. projections)	A-12 Perform data conversions (e.g. between formats)	A-13 Populate GIS feature attributes	A-14 QA/QC data	A-15 Create metadata	A-16 Collect field location data via GPS	A-17 Collect field attribute data					
B	Create Image Data	B-1 Scan hard copy images	B-2 Georeference digital imagery	B-3 Rectify images	B-4 Perform image analysis (e.g. classification)								
C	Maintain GIS Data (1)	C-1 Develop a data maintenance schedules	C-2 Develop GIS procedures (e.g. to update data)	C-3 Edit GIS data (e.g. add, delete, update)	C-4 QA/QC data	C-5 Refresh/ replace layers (e.g. imagery, thematic layers)		C-6 Convert between data formats	C-7 Conduct database performance tuning (e.g. compress, build stats, index)		C-8 Update metadata		
D	Conduct Spatial/ Non-spatial Analysis (4) (Vector, Raster)	D-1 Create Models (e.g. process & scientific models, flow charts)		D-2 Create scripts	D-3 Pre-process Data (e.g. generalize, subset)	D-4 Conduct Geoprocessing (e.g. clip, buffering, overlay, run models)		D-5 Generate statistics (e.g. descriptive, spatial)	D-6 QA/QC Data	D-7 Interpret Results			
E	Generate GIS Products (2) (hard copy, electronic)	E-1 Create maps	E-2 Create analysis reports	E-3 Create charts	E-4 Create tables	E-5 Generate mailing labels	E-6 Create graphic items (e.g. logos, headers, posters, exhibits)		E-7 Distribute digital products	E-7 Distribute hard copy products			
F	Develop Software Applications	F-1 Define user software needs	F-2 Determine application design format (e.g. platform, language)		F-3 Develop software applications	F-4 Customize commercial software	F-5 Create map templates	F-6 QA/QC software applications (e.g. beta test)	F-7 Build help files	F-8 Enhance existing custom applications			
G	Manage GIS Data	G-1 Establish data custodianship	G-2 Organize file structure (e.g. create directories, perform data and directory housekeeping)		G-3 Archive / retrieve data	G-4 Back-up / restore data	G-5 Distribute data according to organizational policy	G-6 Assign data/database permissions					
H	Provide Technical Support	H-1 Resolve user technical problems	H-2 Install Software (e.g. enhancements, service packs)		H-3 Write Technical Guides	H-4 Train GIS end-user(s)							
I	Perform Administrative Tasks	I-1 Correspond with others (e.g. email, mail, phone)	I-2 Write informational reports (e.g. progress, technical, procedural, recommendations)		I-3 Prepare cost estimates (e.g. time, equipment)	I-4 Coordinate GIS projects	I-5 Represent GIS at meetings (e.g. committees, user groups, organizational conferences)		I-6 Maintain equipment/ supplies)	I-7 Maintain contracts	I-8 Supervise Interns	I-9 Participate in public relations activities	
J	Pursue Professional Development	J-1 Participate in professional conferences (e.g. oral, poster submissions, publish/ submit articles)		J-2 Participate in GIS user groups	J-3 Take advanced training courses (e.g. technical training & education courses)		J-4 Cross-train within organization						

Key: *Primary Duty* *(1,2,3,4) Ranking of Duties by Time Spent* *Entry Level Task*